SOME STUDIES OF THE EFFECTS OF TIME, CONCENTRATION AND TEMPERATURE IN SODIUM HYPOCHLORITE BLEACHING OF COTTON

A THESIS

Respectfully submitted in partial fulfillment of the requirements for the Degree of Master of Science in Textile Engineering

by

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1946

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Date Approved by Chairman June 5, 1946

ACKNOWLEDGMENTS

Upon completion of this work I wish to express my most sincere thanks to Professors C. A. Jones and H. A. Dickert of the A. FRENCH TEXTILE SCHOOL of the Georgia School of Technology for their priceless guidance, helpful advice, and constructive criticism. I also wish to express my ever-lasting gratitude to my parents for their unselfish thoughtfulness and sacrifice in giving me the opportunity to carry out the present study.

PREFACE

The bleacher's duty is to remove the color and other non-cellulose materials from the cotton fiber. This separation of the cellulose is to be accomplished in the most efficient and least expensive manner. Bleaching cotton is a cheap method of purifying cellulose.

The first bleaching processes were crude and inefficient. After several centuries of experience and efforts to improve the art, it was realized that something more than experience was needed. It was then that work and study were begun in a scientific manner. All the operations performed in the bleaching process are organic or inorganic chemical reactions. The results so far accomplished through science and research make reasonable the expectancy of greater developments in the future.

In spite of the enormous amount of research performed investigating the products of cellulose degradation, a great deal remains to be discovered. Oxycellulose and hydrocellulose are the most common products of cellulose degradation, yet, a simple method of determining quantitatively their presence in overbleached materials has not been found. Cellulose research is being continued on a large scale and some day, no doubt, it will be possible to refer to this substance with a definite knowledge of its chemistry.

Nevertheless, the knowledge that is available today on the hypochlorite bleach is ample for the performance of the present study. It is necessary to note here that the present work represents only one approach to the subject. Bleaching is not a trial and error industry and there is a scientific reason for every operation performed. By scientific control of the processes and materials used, better products and reduced cost are obtained. Bleaching, which started as an art many centuries ago, has become a science and as such it has its laws and principles.

PURPOSE

This work is an attempt to determine ideal bleaching conditions as affected by concentration of hypochloride bleaching solution, time and temperature of treatment.

The process which will result in the best degree of whiteness with the least amount of cellulose degradation is considered ideal. Such conditions are first to be found and the cost of their application in industry would determine whether or not they are practical. The present work does not intend to consider cost, but this must be given due consideration in future studies if the ideal conditions of bleaching are to be judged from a practical standpoint.

GENERAL CONCLUSION

After completing the present study, the conclusions reached are here summarized.

It has not been found possible to bleach cotton fabric by the sodium hypochlorite method without a certain amount of loss in tensile strength.

The whiteness of the bleached fabric although very satisfactory for commercial bleaches, is not one hundred percent pure.

The best bleaching conditions found are not ideal. H owever, they produce satisfactory results from the standpoint of whiteness and loss in tensile strength.

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SECTION I

GENERAL DISCUSSION

I. HISTORY OF BLEACHING

When did man first conceive the idea of producing white fabrics? This is a question that has puzzled historians for many years. The truth is that in the early times there was not a clear difference between bleaching and laundering. To us, bleaching means the production of white fabrics or garments before they are used. On the other hand, laundering is the cleansing of such fabrics or garments after they have been used or worn.

For the sake of clarity, we will only attempt to give a general picture of the procedures used. In all cases we will refer to those processes which will come closer to our modern conception of bleaching. It is proper to state here that bleaching, in the early days of its use, consisted mainly in the removal of impurities in fabrics without attempting to destroy the natural coloring matter in the fabric. It was more a scouring process than bleaching.

From early Egyptian printings, it is known that fabrics were boiled, but there is no indication as to what chemicals were used. To our understanding it is very probable that the only substance used was water. In Egypt cotton and linen fabrics were used, but in all cases they were gray goods. As a matter of fact, the linens used in the preparation of the mummies were gray fabrics.

Jeremiah and Malachi mention in the Bible the alkaline plant boreeth.[1] This could be an indication of man's first attempt to use chemicals in the cleansing of fabrics. Even today some Nomad tribes in Arabia use various kinds of herbs for cleansing cloth.

In Pompeii washing was carried out in special establishments named fullonica. The fullonica was a white marble building equipped with fountains and cisterns for washing. Through pictures preserved from those days, the process carried out in these establishments is clearly explained. It seems that the people of Pompeii discovered the bleaching action of sulphur when burned by producing sulphurous acid.

The discovery of soap is ascribed to the Gauls. It seems that at first this substance was used among the ancients as a pomade for cleansing the hair. However, later it was used for cleansing fabrics. In Pompeii the remains of a soap factory have been found. Pliny states that the soap was made from tallow and the roots of certain poppies, sometimes from radicula, which is supposed to be identical with our saponaria. But before the discovery of soap, other substances such as potash, nitre, and various earths were employed.

The different substances mentioned were used along with water to give a scouring action to the cloth. The first treatment of the cloth was a boil in a liquor having an alkaline reaction. Pliny gives a description of the method

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[1] Higgins, S. H. "History of Bleaching", p. 4, Longmans, Green, & Co., London, 1924.

employed by the Gauls for the cleansing and whitening of their textile fabrics. They made use of an alkaline substance known as lixivium, which was extracted from the ashes of burnt wood or other vegetable matter, and also apparently employed this alkaline combination with oils in the form of soaps. They are also credited with a process of burning lime to give a useful scouring agent.

The primitive methods of bleaching, confined more especially to linen since cotton was considered white enough for all practical purposes, required the exposure of the cloth on large grassy meadows for a considerable period of time. This necessitated not only the expenditure of a vast amount of labor and time but also the expense of land rent, since the care of bleaching fields was considerable. In the early part of the eighteenth century extensive fields were established in Ireland for the bleaching of linen. In the Irish method, the alkaline liquors obtained from the ashes of sea-weeds - kelp - were used for steeping and boiling the cloth. The steeping process usually occupied several days, after which the linen was thoroughly washed and spread out on the grass for a period of several weeks.[2]

The steeping or boiling in the alkaline liquor was known as bucking or bowking and the exposure on the grass was called crofting. In order to obtain a satisfactory bleach, these two processes were alternately repeated, often five to

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[2] Matthews, J. M. "Bleaching And Related Processes", p. 9, The Chemical Catalog Company, Inc., New York, 1921.

six times. After exposure on the grass, the linen was steeped for several days in sour milk, then washed clean and again spread on the grass.

Before bleaching was taken up as a national industry in Ireland, it was practiced principally in Holland, and, up to the middle of the eighteenth century, it could almost be said that the Dutch held a monopoly of the bleaching trade for the rest of Europe. This transfer of the cloth from any country to Holland and back again, together with the time required for bleaching, occupied a period of about six months.

The method of bleaching in Holland consisted in a general way as follows. The goods were first steeped in a weak lye and then in a hot potash lye for about a week. After this, it was given a thorough washing and then steeped in buttermilk for several days. An exposure in a moistened condition on the grass for several months of summer followed and completed the bleaching operation.

The action of sour milk in bleaching was evidently due to its acid constituents, which rendered the impurities in the fabric more soluble. This beneficial action of acids was realized by Dr. Home of Edinburgh, who showed that by substituting a dilute solution of sulfuric acid for the sour milk, better results could be obtained and at less expense. The treatment with dilute sulfuric acid for twenty-four hours gave as good results as steeping in sour milk for a week or more. Even with this improvement, however, the proper bleaching of linen goods required a period of four to six months.

With the invention of the power loom, the output of materials was increased to such a point that the methods of bleaching were not satisfactory any longer. It meant, for the manufacturers, the use of larger capital, and the turn-over was very slow. It was necessary to develop new methods of obtaining a satisfactory bleach in shorter periods of time in order to cope with the increased output of goods.

Chlorine gas was discovered in 1774 by the Sweedish chemist Scheele. The name of the gas was at first diphlogisticated marine acid gas. This name was given in consequence of the idea that the gas was the result of withdrawing phlogiston from muriatic acid.[3] The bleaching properties of this gas were not studied with reference to their commercial application until 1785. It is significant to notice that these studies coincided with the manufacture of soda on an industrial scale. Berthollet was the first chemist to point out the commercial possibilities of chlorine as a bleaching agent for vegetable fiber materials. An aqueous solution of the chlorine gas was used, and the goods were passed through the hot solution. It was a number of years before the proper method of using the new bleaching agent was learned, and it did not come into general practice or favor until an alkaline solution of the gas was employed. Berthollet used the alkali potash as an absorbent and thus produced Eau De Javelle. Even today this name is applied to a solution of potassium hypo-

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3 "Chlorine In Bleaching", Textile Colorist, Vol. LII (1930), p. 844.

chlorite. It can very well be said that Berthollet created the first hypochlorites, although he did not live long enough to investigate the chemistry of such product to a great extent. In 1789 Tennant, of Glasgow, patented a process for producing a very efficient liquor by saturating lime water with chlorine gas. This process revolutionized the methods of bleaching and cut down the time required from several months to a couple of days, or even less. Tennant, a few years later, was successful in manufacturing a dry chloride of lime or bleaching powder, obtained by saturating quicklime with chlorine gas. This preparation quickly came into favor as the principal bleaching agent for linen and cotton goods.

The succession of developments in the use of chlorine was apparently as follows: Chlorine gas, chlorine water, chlorine absorbed in alkali and chloride of lime.[4] At this stage, bleaching became more of a scientific process. With the use of chemicals in all phases of processing, it became imperative for the bleach works to hire the services of chemists. It can be said also that the bleaching industry was the first textile group to recognize the need of scientific knowledge in the practical processing. However, before such facts were acknowledged, there was a great deal of prejudice and unbased distrust in the use of acids, lime and chlorine in the bleach house.

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4 "History Repeats Itself in the Bleaching Industry", Textile Colorist, LIII (1931), p. 123.

The next steps in the direction of improving the methods of bleaching, both with respect to the qualities of the goods and the time consumed in the process, was the introduction of suitable machinery to supplant manual labor. This leads to a greater simplification of the processes employed and a more economical use of the various chemicals needed. The so-called American Process came into vogue about 1837 and, with minor improvements, is still the method in general practice. In brief outline, this process consisted of singeing, washing, boiling under pressure with lime, souring with weak acid, boiling under pressure with alkali and resin soap, steeping in a solution of bleaching powder, souring again with weak acid, and finally washing, tinting, and drying.

From 1837 until today there has not been any change in the fundamentals of chlorine bleaching. The only changes that have come into the process are changes in the design of the equipment used, improvements in the chemicals used, and reduction in their cost. More stable hypochlorite compounds have been produced and credit must be given to the Mathison Alkali Works for the production of H.T.H. This is a trademark for a very stable hypochlorite that is guaranteed to give at least 70% available chlorine. This new product came into the market in 1930.[5] Some years later, this same company put out a new product - Textone. Textone is a sodium chlorite

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5 Savell, W. L. and Ivey, J. W., "Uses and Misuses of Chlorine in Textile Bleaching", American Dyestuff Reporter, XX (1931), pp. 97-100.

which has very high oxidizing properties and is an efficient bleaching agent. This product is used in conjunction with H.T.H.[6]

In the same line of development of new bleaching agents with a chlorine base, organic compounds of chlorine have been produced, i.e., by treating insoluble dichloroamides of aromatic sulphonic acids with alkalis or alkaline salts.[7]

In one way or another, the industry's aim has always been to shorten the time required for bleaching. To use more efficient and cheaper methods and products is another of the main objectives of the bleaching industry. As a whole, it can be stated that there is an intensive program of research being conducted along these lines in the field of cotton bleaching.

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6 Vicent, Y. P., Durbean, A. L. and Syuan, J. F., "Bleaching Cotton Goods with Hypochlorite", American Dyestuff Reporter, XXX (1941), pp. 358-60.

7 Chem. Fab. von Heyden A.-G., "Powder Yielding Active Chlorine", Journal of the Society of Dyers and Colorists, XLVIII(1932), p.39.

II. THE CONSTITUENTS OF THE COTTON FIBER

The cotton plant belongs to the natural order Malvaceae, the mallow family. Botanicaly, it is known by the generic name Gossypium, derived from Gossypion, this being the name by which, according to Pliny, cotton was known in the island of Tyles.[8]

The cotton fiber used for textile purposes is the fruit of the plant. The hairs are a protective cover to the seeds and in most cases are firmly fixed to them. The fibers of the cotton plant are of two types. These two types are the long fibers or hairs, which are used in the manufacture of yarns and fabrics, and the short fibers or fuzz, which are used as a source of cellulose in the manufacture of rayons and high grade papers. In some varieties of Gossypium one of these two kinds of fibers predominates. In the case of Egyptian cotton, the long hair fibers are the one type found. On the other hand, in the case of Upland cotton, about ten percent of the lint is short fibers.[9] On the average, the cotton fiber will range in length from one-sixteenth of an inch on up to two inches. The diameter of the fibers is inversely proportional to the length

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[8] Johnson, W. H., "Cotton and Its Production", p. 18, MacMillan and Co., Limited, London, 1926.

[9] U.S. Department of Agriculture, "The Cotton Plant", p. 93, Government Printing Office, Washington, 1896.

ranging from 0.0004 to 0.00104 inches.

Each independent fiber is produced by the outgrowth of a single epidermal cell from one of the cotton seed in the forming fruit. Until the cell bulges out on the outer side, it appears the same as all other epidermal cells. Certain of the epidermal cells produce outgrowths that continue lengthening until the long lint hair, or fiber, is made; other cells produce outgrowths at first but which stop growing before attaining much length. These short epidermal hairs are the fuzz.[10]

A perfect and typical cotton fiber would, when fully matured, consist of four parts. They are:

1. An outer cuticle or integument which is perfectly continuous and which forms the skin or sheath of the fiber.

2. An inner tube or layer of more or less homogeneity attached to the inner surface of the outer layer, formed by successive deposits of cellulose and coagulated protoplasm and other cell-contents and which forms the substance of the fiber.

3. An inner layer attached to the interior of the secondary deposit and which seems to be of a firmer consistency and frequently exhibits indications of spiral structure when treated with reagents.

4. A pith-like deposit, containing any endochrome which may be present in the fiber, and more or less filling up the central cavity or lumen or simply existing in detached

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[10] Brown, H.B., "Cotton", p. 123, McGraw-Hill Book Company, Inc., New York, 1927.

and not continuous pieces.[11]

Distributed in these four parts of the cotton fiber are its constituents. These substances are: Waxes, proteins, mineral matters, pectic matters, coloring matters, and cellulose. These constituents either form part of the fiber structure itself or represent impurities in the fiber which would not be found in all varieties of cotton.

1. Waxes. Fats and oils are frequently stored as reserve foodstuffs in plants and waxes pass beyond the walls, forming a layer on the outer surface. The formation of fat is due to the decomposition of the protoplasm, oil drops being formed. Generally speaking, in the cotton fiber natural waxes and fats amount to 0.61 percent on the average. This waxy covering of the fiber is desirable in the manufacture of yarns, and, therefore, no attempt is made to remove it until the time of bleaching or finishing. The waxes render the fiber more plyable and improve its spinning properties.

On extracting cotton with benzene, then treating with acid, washing, drying and again extracting with benzene, the cotton yields more fat to the benzene. This crude wax, having the appearance and consistency of bees-wax, on treatment with petroleum spirit resolved into two constituents - Cotton Wax A to the amount of seventy percent soluble in the above spirit and Cotton Wax B insoluble in petroleum. Cotton Wax A has a pale color, melts at 66 to 67 degrees centigrade

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11 Bowman, F. H., "The Structure of the Cotton Fiber", p. 101-102, McMillan and Co., Limited, London, 1908.

and consists for the most part of a true wax, containing, besides some free fatty acids, small amounts of glycerides and some hydrocarbons. Cotton Wax B is a dark green, granulated but plastic substance, melting at 68 degrees centigrade and containing very little free fatty acid.[12]

All the waxy and fatty matters are present on the outer cuticle covering the fiber. These products render the fiber quite water repellent, although they contribute greatly to the spinning qualities of cotton.

2. Proteins. Proteins are closely incorporated with the protoplasm of plants, and the original construction of the protein matter, like that of carbohydrates, seems to be carried out only by the vegetable protoplasm. Sulfur and nitrigen are constituents of all proteins, and proteins are found in all protoplasms. In the cotton fiber, the proteins are present along with the secondary layer, and seem to be produced at the time of the formation of the cuticle. These substances amount to about one and one-half percent of the total weight of cotton.

Some proteins are soluble in water, some are insoluble. Others are soluble in aqueous solutions of neutral salts. Nearly all are insoluble in alcohol or ether but a few are soluble in a mixture of alcohol and water. They all dissolve in strong mineral acids and caustic alkalis but are

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[12] Higgins, S. H., "Bleaching", p. 11, Longmans, Green & Co., London, 1921.

somewhat changed in the process.[13]

3. Mineral Matters. The mineral matter usually consists of phosphates and chlorides of potash, soda and magnesia, small quantities of lime, and the sulphates. These bodies are in combination with various organic constituents of the fiber. The nature and amount of the mineral matter found in cotton varies with the composition of the soil in which it is grown. In a general way it can be said that as an average, the mineral contents of cotton is 1.65 percent.

The mineral constituents were quantitatively examined by Dr. Ure, and he found that in a sample of Sea Island cotton they amounted to very nearly one percent of the weight and yielded on analysis the following results:[14]

Carbonate of potassium.....	44.80%	Soluble in water
Chloride of potassium	9.90	Soluble in water
Sulphate of potassium	9.30	Soluble in water
Phosphate of lime	9.00	Soluble in water
Carbonate of lime	10.60	Insoluble in water
Phosphate of magnesia	8.40	Insoluble in water
Peroxide of iron	3.00	Insoluble in water
Traces of alumina and loss..	5.00	Insoluble in water
	100.00%	

4. Pectic Matters. Pectins occur in the intercellular

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[13] Higgins, S. H., "Bleaching", p. 15-17, Longmans, Green & Co., London, 1921.

[14] Bowman, F. H., "The Structure of the Cotton Fiber", p. 249, MacMillan and Co., Limited, London, 1908.

spaces between the cells of fibers. They are complex bodies, being a mixture of several chemical simple compounds. Pectose exists along with cellulose in the substance of most cell walls. Pectic bodies are found to be prominent in the layers of the cell wall, remote from the protoplasm, and cellulose in those nearest to the interior of the cell. Pectic bodies are regarded by some chemists as compounds of carbohydrates of varied constitution with acid groups. Then cellulose is sometimes converted into lignine in the plant, this body being probably a mixture of substances formed successively from cellulose. Mangin has shown that pectic matters consist of two classes of substances. First, neutral bodies resembling pectose, which is an insoluble compound closely resembling cellulose in its properties, and bodies of a gelatinous nature soluble in water, known as pectins. Second, feintly acid substances, the principal member of the group being pectic acid, which occurs in nature as calcium pectate.[15] On the average, the cotton fiber contains about 1.8 percent.

5. Coloring Matters. Coloring matter is present to a small extent in cotton and gives the fiber a slight yellowish brown tone. The percentage of this substance present is approximately 1.7 on the average. The coloring matter of raw cotton consists of two organic pigments, the one soluble in alcohol and the other dissolved only by boiling alcohol. These coloring matters are insoluble in water and only partially soluble in alkaline or acid solutions. By the action of oxidizing agents

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15 Higgins, S. H., "Bleaching", p. 21-23, Longmans, Green & Co., London, 1921.

they are either destroyed or changed to a soluble colorless compound. These pigments are not so easily attacked by reducing agents in which case they would become insoluble colorless compounds readily oxidized to their original color.[16] Marchlewski obtained the coloring matter of cotton in crystals, which, he stated, had the composition $C_{13}H_{14}O_7$. He named this substance gossypol. It dissolved readily in alkalis to an intensely yellow-colored solution, and also in sulfuric acid to give a characteristic crimson color.[17]

6. Cellulose. The cell wall is formed from the protoplasm or secreted by it, and it is usually known as cellulose. The thickening of the cell wall is a similar decomposition of the protoplasm. The plant produces from the carbon dioxide of the air, firstly, sugar, and subsequently starch and cellulose. It is the essential constituent of the vegetable cells. Cellulose belongs to the group of chemical compounds known as the carbohydrates. Some of the carbohydrates are preserved by the plant as a reserve food, and are subsequently used by it. Some are used to form a considerable thickening of the cell walls, thus affording a permanent strengthening of the plant. Cellulose accounts for better than ninety percent of the composition of the cotton fiber. This percentage will vary with the different varieties of cotton.[18]

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[16] Matthews, J. M., "Bleaching and Related Processes", p. 204, The Chemical Catalog Company, Inc., New York, 1921.

[17] Higgins, S. H., "Bleaching", p. 23, Longmans, Green & Co., London, 1921.

[18] Higgins, S. H., "Bleaching", p. 24-28, Longmans, Green & Co., London, 1921.

The percentage composition of all kinds of cellulose is represented by the formula $C_6 H_{10} O_5$, but it is certain that some multiple of this must be taken to represent the molecule. The exact multiple is a matter of considerable uncertainty, and, hence, the formula is written generally as $(C_6 H_{10} O_5)_n$.

The constitution of cellulose is still unknown, although it has been the subject of much investigation. The importance of this problem is equalled by the difficulty of its solution, and the composition of cellulose has become almost a special branch of organic chemistry. The molecular weight cannot be determined, since no known solvent dissolves cellulose without changing its chemical properties and physical condition. Owing to its colloidal nature and consequent complexity, the products of its decomposition are not easy to separate and determine quantitatively. This must be done before any attempt can be made to prepare a chemical compound by synthesis.

The chief facts connected with the chemistry of cellulose are:[19]

1. It contains hydroxyl groups. Four are possibly present in each $C_6 H_{10} O_5$ unit, since, when cellulose is heated with acetic anhydride and zinc chloride, a tetraacetate, $C_6 H_6 O(OOCCH_3)_4$, is produced. This lead Cross and Bevan to

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19 Trotman, S. R. and Thorp, E. L., "The Principles of Bleaching and Finishing of Cotton", p. 85-121, Charles Griffin & Company, Limited, London, 1927.

propose, originally, the formula $C_6H_6O(OH)_4$. It may be noted, however, that Perkin and Green could not prepare a cellulose acetate containing more than three acetyl groups. These hydroxyl groups must be alcoholic in nature, and since, when oxidized, both carboxyl and ketone groups are introduced, both primary and secondary alcoholic groupings must be present, that is, the molecule contains both CH_2OH and CHOH groups.

2. Cellulose itself does not reduce Fehling solution nor form hydrazones when treated with phenyl-hydrazin. Nor does it exhibit any of the properties of an acid. Hence, neither carboxyl nor carbonyl groups can be present.

3. When cellulose is completely hydrolyzed by dilute acids, it gives dextrose, $C_6H_{12}O_6$, the constitution of which is known, while partial hydrolysis produces bodies having reducing properties, i.e., containing carbonyl groups.

4. Under the influence of acetic anhydride an octa-acetate of cellobiose, $C_{12}H_{22}O_{11}$, is produced, while laevolglucosan is obtained by destillation under reduced pressure.

5. Since derivatives of benzene can be obtained from cellulose, it is assumed that it is built on the type of a closed ring as opposed to an open chain. Further, the group $CO\text{-}CH_2$ must be present, because, when cellulose is fused with alkalis, hydrogen, and carbonic, acetic and oxalic acids are formed.

Gross and Bevan, the chief authorities on this subject, group the simple celluloses into:

(1) Those with the maximum resistance to hydrolysis and containing no active ketone groups. When hydrolyzed by dilute acids, they yield dextrose. This group includes the cellulose of common textile fiber, such as cotton, flax, ramie, and hemp.

(2) Those with resistance to hydrolysis and containing active ketone groups, being, in fact, oxycelluloses.

(3) Those of low resistance to hydrolysis, i.e., fairly readily decomposed by acids or alkalis, with the formation of carbohydrates of low molecular weight. They are termed also hemi or pseud celluloses.

In addition to these, there are also some complex celluloses termed compound celluloses. These include lignocelluloses, pectocelluloses and mucocelluloses, and cutocelluloses and adipocelluloses.[20]

Pure cellulose is a white, odorless, tasteless substance which retains the organized structure of the material from which it was prepared. Its specific gravity is 1.5. It burns freely in air with a luminous, smokeless flame. It is hygroscopic, absorbing up to eighteen percent of moisture when exposed to a damp atmosphere, above eighty percent relative humidity. When heated to a temperature of 150 degrees centigrade, it becomes brown in color. If the heating is continued at this temperature or the temperature raised, the cellulose decomposes and acid vapors are given off. Prolonged exposure

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[20] Trotman, S. R., "The Bleaching, Dyeing, and Chemical Technology of Textile Fibers", p. 119-129, Charles Griffin & Company, Limited, London, 1925.

to air or heat for a shorter period at a temperature below 150 degrees centigrade converts it gradually into a body termed oxycellulose. Cellulose is insoluble in either cold or boiling water, and also in organic solvents. It dissolves in cold concentrated sulfuric and hydrochloric acids, being subsequently hydrolysed to dextrose. It is soluble also in Schweitzer solution, concentrated zinc chloride, or calcium thiocyanate solutions. It absorbs acids and alkalis to a limited extent, and also certain salts such as copper sulfate. It is not attacked readily by alkalis in the absence of air, though if oxygen is present, oxycellulose is produced. Cellulose possibly combines with water, giving hydrated cellulose, $(C_6H_{10}O_5)_2.H_2O$, which is present in mercerised cotton. Cellulose is fairly stable, but, under suitable conditions, is attacked by certain enzymes and bacteria.

As stated before, the constitutional formula of cellulose is as yet unknown. However, from the compilation of the experimental observations existing and a few isolated facts, some theories have been brought forward and some structural formulas suggested. In this field Cross and Bevan, Tollens, Hibbert, Cleve and Euler, Irvine and Hirst, Perkin and Green, Hess, and many others have contributed with their work.[21]

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[21] Henser, E., West, C. J. and Esselen, G. J., Jr. "Textbook of Cellulose Chemistry", p. 179-203, McGraw-Hill Book Company, Inc., New York, 1924.

III. NON-CELLULOSE CONSTITUENTS OF THE COTTON FIBER ELIMINATED BY BLEACHING

The most important operation of cotton bleaching is not, curiously enough, the actual destruction of the coloring matter but the cleansing operations which are preliminary to chemicking. Bleaching itself starts with the singeing of the goods upon their arrival to the bleach house. The mere treatment of a fabric with hypochlorite, or any other bleaching agent, will not produce a good permanent white. This is due to the natural impurities of the cotton fiber and the impurities added to it in the manufacture of the textile materials. As stated in previous discussions, the bleaching process is the separation of all impurities from the cellulose. Therefore, the bleaching operation aims to remove as much as possible, if not all, of the natural and added impurities.

The natural impurities removed are: Waxes and fatty matters, proteins, mineral matters, pectic matters, coloring matters, and motes. The added impurities are: Sizes applied previous to weaving, oils applied in spinning, and dirt and stains that may have been accumulated in handling the goods.

The waxes and fatty matters are removed in the scouring of the goods. This process consists in boiling the material over a period of several hours in an alkaline bath with the aid of some penetrants and assistants. The general

reaction of these chemicals with the waxes and fats, is saponification. After the impurities are saponified, they become soluble and are definitely removed by further washing. The removal of waxes and fats has to be as complete as possible. These substances make the cotton fiber water repellent to a great extent. However, the fact that the fibers will take up water more or less readily does not necessarily mean that all the waxes and fatty matters have been removed. These substances are of various kinds and are removed by varying degrees of treatment. If all of such impurities are not removed previous to the hypochlorite treatment, the bleaches obtained, satisfactory as they may be at first, may turn yellow upon storage.

The proteins present as natural impurities of the cotton fiber are removed by the alkaline treatment and following wash. These substances, of high nitrogen content, will hydrolyze by boiling in alkaline liquors. It has been proved that the proteins present in the fiber will decompose upon this treatment and give off ammonia. The evolution of this gas accounts for the peculiar smell of the kier house in bleachworks. Proteins have to be removed before the hypochlorite treatment in order to prevent the formation of chloroamines which are detrimental to the tensile strength of the material upon drying. This tendering is due to the oxidizing properties of these compounds. However, the removal of the protein content of cotton is hardly taken into consideration due to the fact that the same treatment that will remove the waxes and fats from

the cotton fiber will remove these nitrogenous compounds also.

The mineral matters found in the cotton fiber are removed by two means. The substances soluble in water will be dissolved during the washings of the goods and thus removed. The substances insoluble in water will be reduced to a great extent by the action of the alkaline boil and mechanical handling of the goods. Although it is desirable to obtain as pure cellulose as possible by bleaching, it cannot be said that the natural mineral contents of cotton will interfere in the production of a good, satisfactory bleach. There has been very little work recorded in the elimination of mineral impurities in cotton. This has been due greatly to the unimportance of the presence of such substances in the finished product as commercial whites. However, it has been found that after the caustic soda-hypochlorite bleach only five percent of the original mineral contents remained in the fiber. This determination was made by analysis of the ash residue after burning the cotton. Higgins found that as the non-cellulose constituents were removed, the ash decreased in about the same ratio. There was not a great decrease in weight after the scouring and also the ash contents remained constant.[22]

The pectic matter is also removed by the alkaline boil. The amount of such substances is very small, but it is desirable to remove as much as possible. It is interesting

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22 Higgins, S. H., "Bleaching", p. 51-52, Longmans, Green & Co., London, 1921.

to note that a treatment with dilute hydrochloric acid will remove these impurities. Pectic matters have a natural dark color of their own, and, when in the cotton fiber, they give its characteristic yellowish tint to a certain extent. In order to obtain a pure white, the pectic matters present must be eliminated. By action of boiling, dilute, alkaline solutions, the non-cellulose portion is gydrolyzed, first to pectine, then to metapectine, and, finally, to parapectic acid, the solutions which are gelatinazed by the alkaline treatment.

The coloring matters are not affected by the alkaline boil. These impurities have to be removed by other means. It is here that the bleaching agents are used. The methods for removing such coloring matter are two - first, to reduce the coloring matter to a colorless leuco compound by the action of nascent hydrogen and, second, by the formation of a colorless leuco compound produced from the action of nascent oxygen. In the case of nascent hydrogen, the colorless compounds formed are not soluble and when left in the goods may be later oxidized back to their original color, and the stain of the coloring matter would be noticeable after the goods have been stored for some length of time. In the case of oxygen, the coloring matter is oxidized to soluble, colorless compounds which can be removed by further washing. Thus, for the reason that the oxidized compounds are all soluble, the oxidizing process has found a more vast application. If the goods have had a good alkaline treatment and a reasonable bleaching, the white obtained on them should be very satisfactory.

The motes present in all gray materials manufactured from raw cotton, to a greater or less extent, are not impurities present in the fiber itself, but they are natural impurities present on the cotton fiber. The motes have their origin at the cotton gin. The motes are small pieces of cotton-seed and broken leaf particles produced by ginning. Since the motes are of vegetable origin, it is logical to expect them to have a composition similar to cotton. The only difference is the different proportions of the constituents. As in the case of cotton, most of the impurities present in the motes is eliminated by the alkaline boil. The remaining coloring matter is eliminated at the bleaching operation. However, it is interesting to note that the motes are not removed from the fabric but that they are bleached along with the cotton.

The removal of the added impurities of the cotton fiber is accomplished in a similar manner to the removal of the natural impurities, except in the case of the size. The oils and stains are removed by the alkaline boil through the saponification of the substances. The dirt collected by the goods is removed either by solution in the washing water or by the alkaline treatment. In the case of size, the method used is different, although it could also be removed to a great extent in the alkaline boil. However, this is dangerous to a certain extent and detrimental to the efficiency of the equipment and chemicals used. Therefore, methods of desizing are used. These methods will be taken up later on.

IV. CHEMISTRY OF THE HYPOCHLORITES

The removal of the coloring matter remaining on the cotton fiber after scouring is accomplished by means of the bleaching agents proper. These bleaching agents may belong to either one of the two general groups - reducing agents or oxidizing agents. As it was stated previously, the most suitable bleaching substances are those that will oxidize the coloring matter to soluble bodies which can be removed by washing. Of these agents the cheapest and most efficient are the hypochlorites.

The chemistry of the hyopchlorites is by far more complicated than the mere reaction of chlorine with some alkali. In order to make this statement clearer, it is necessary to follow the formation of hypochlorites from their main source - chlorine gas.

Chlorine is a greenish yellow gas, possessing a very pungent odor. When inhaled, it attacks the mucous membrane of the nose, throat and lungs, thus causing death by suffocation. It is readily liquified by cooling it to-34 degrees centigrade when it forms a yellow liquid which freezes at-102 degrees centigrade. Liquid chlorine has been for some time an article of commerce. Chlorine gas is 35.5 times as heavy as hydrogen or 2.45 times as heavy as air. It is moderately soluble in water. One liter of water at 0 degrees centigrade dissolves 3.43 liters of gas and 3.00 liters at 17 degrees. If the aqueous

solution be frozen, crystals of chlorine octahydrate, $Cl_2.8H_2O$, are formed. But, when chlorine is dissolved in water, some of the water is decomposed with the formation of hypochlorous acid, thus

$$Cl_2 + H_2O \rightleftharpoons HCl + HOCl$$

This reaction is reversible, and, when the concentration of the chlorine exceeds one-tenth of one gram per liter, it goes back from right to left so that free chlorine is again formed. If a solution of chlorine is kept for some time, a second reaction takes place, resulting in the formation of nascent oxygen, thus[23]

$$H_2O + Cl_2 \rightleftharpoons 2HCl + O$$

Another factor that will control the reversibility of the equation when chlorine is dissolved in water is the concentration of the hydrochloric acid formed. When the quantity is small, the reaction proceeds from left to right, forming hypochlorous and hydrochloric acid, until a state of equilibrium is reached. As soon as the concentration of hydrochloric acid is increased beyond this point, either by direct addition or by increasing the concentration of chlorine, the reaction tends to be reversed and the hypochlorous acid is decomposed as quickly as it is formed. In the presence of large excess of hydrochloric acid, hypochlorous acid cannot exist at all.

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23 Trotman, S. R., "The Bleaching, Dyeing and Chemical Technology of Textile Fibers", p. 267, Charles Griffin & Company, Limited, London, 1925.

It is clear that if the hydrochloric acid be removed as quickly as it is p roduced, much more concentrated solutions of hypochlorous acid could be obtained from the action of chlorine on water. Now, while hydrochloric acid is a strong acid, hypochlorous acid is a very weak one, being unable to decompose even carbonates. Hence, if powdered calcium carbonate be suspended in the water, the hydrochloric acid will be neutralized, while the hypochlouous acid remains in the solution, thus[24]

$$2HCl + CaCO_3 \longrightarrow CaCl_2 + H_2CO_3$$

On the other hand, if slaked lime is saturated with chlorine gas, a double chloride and hypochloride of calcium is formed, thus

$$Ca(OH)_2 + Cl_2 \longrightarrow Ca(OCl)Cl + H_2O.$$

The product of this reaction is known as bleaching powder. However, there has been much controversy as to the action of chlorine upon lime and the constitution of the product formed. For the general purposes of textile chemistry, the formula Ca(OCl)Cl is perfectly satisfactory, but it is interesting to go into the discussion of the several theories formulated and the reasons that sustain such hypothesis.

Bleaching powder was regarded at one time as a mixture of calcium chloride and calcium hypochlorite, but this hypothesis is not in accordance with its properties, and was soon given up.

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24 Trotman, S. R. and Torp, E. L., "The Principles of Bleaching and Finishing of Cotton", p. 426-428, Charles Griffin & Company, Limited, London, 1927.

It is true that its aqueous solution contains both calcium chloride and hypochlorite, but these are formed during the process of solution. Calcium chloride is a very deliquescent body, but bleaching powder is not. Further, like other deliquescent compounds, it dissolves rapidly in alcohol; but no calcium chloride can be extracted from bleaching powder by this solvent. Finally, a molecular mixture of calcium chloride and hypochlorite would be much more soluble in water than is bleaching powder.

Odling proposed the formula $CaOCl_2$. According to this view, when the powder is treated with water, the following change occurs.

$$2Ca(OCl)Cl \longrightarrow CaCl_2 + Ca(OCl)_2.$$

The chief difficulties in connection with this formula are that it does not explain the presence of free lime which is always found in bleaching powder to the extent of ten to fifteen percent nor is it quite in accordance with the fact that no calcium chloride can be extracted with alcohol.

Stahlschmidt considers that the formation of bleaching powder is represented by the equation

$$3Ca(OH)_2 + 2Cl_2 \longrightarrow 2ClOCaOH + CaCl_2 + 2H_2O$$

According to this view, it is a mixture of a basic hypochlorite and calcium chloride. In the presence of water the the chloride dissolves, while the basic salt decomposes yielding hypochlorite and free lime.[25]

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[25] Trotman, S. R. and Torp, E. L., "The Principles of Bleaching and Finishing of Cotton", p. 434-435, Charles Griffin & Co., Limited, London, 1927.

Attempting to explain the presence of free lime, von Tiesenholt regards bleaching powder as being formed in accordance with the equation[26]

$$2Ca(OH)_2 + 2Cl_2 \rightleftharpoons Ca(OCl)_2 + CaCl_2.2H_2O.$$

This reaction he regards as reversible, and, hence, never complete in either direction. Thus free lime is always present.

Dietz,[27] as the result of experiments on the action of dry and moist carbon dioxide on bleaching powder, concludes that the formation of bleaching powder is expressed by the equation.

$$2Ca(OH)_2 + Cl_2 \longrightarrow CaOCa(OCl)Cl.H_2O + H_2O.$$

This compound, in the presence of water, tends to react as follows, producing free lime:

$$CaOCa(OCl)Cl.H_2O + H_2O \longrightarrow Ca(OH)_2 + Ca(OCl)Cl.H_2O.$$

Thus, free lime is now available for the absorption of more chlorine, in accordance with the first equation. This explains the necessity for the presence of more moisture in the lime than is required to convert it into the hydroxide, $Ca(OH)_2$, the extent to which this second reaction takes place, being governed by this factor. The final reaction is

$$2nCa(OH)_2 + (2n-1)Cl_2 \longrightarrow (2n-2)Ca(OCl)Cl.H_2O + CaOCa(OCl)Cl.H_2O + H_2O$$

A sample might, therefore, be produced of any composition between $CaOCl(OCl)Cl.H_2O$, containing 35.32 percent of

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[26] Journal of the Society of Chemical Industry, XX (1901), p. 248.
[27] Journal of the Society of Chemical Industry, XX (1901), p. 247.

chlorine, and $Ca(OCl)Cl.H_2O$, containing 48.96 percent of chlorine.

Winteler[28] concludes that bleaching powder cannot be represented by a simple formula but is undoubtedly a mixture of bodies, among which are basic calcium chloride and hypochlorite.

Tarugi[29] argues that the formula $CaO_2Cl_2.H_2O$ is in accordance with the properties of bleaching powder, pointing out that it quantitatively converts mercury into mercury chloride, as shown by the equation

$$CaO_2Cl_2 + Hg \longrightarrow CaO_2 + HgCl_2.$$

He regards the formation of bleaching powder to be due to the presence of slaked lime of calcium peroxide, $CaO_2.H_2O_2$, and suggests the following series of reactions.

1. - $2Cl_2 + 2H_2O \longrightarrow 4HCl + O_2$
2. - $CaO_2.H_2O + 2HCl \longrightarrow CaO_2Cl_2 + 2H_2O$
3. - $CaOH_2O + O_2 \longrightarrow CaO_2H_2O_2$
4. - $CaO_2H_2O_2 + 2HCl \longrightarrow CaO_2Cl_2 + 2H_2O$

Another hypochlorite used in the bleaching of cotton to a great extent at the beginning of the nineteenth century was Eau De Javelle. This was the first true hypochlorite produced and used in the bleaching industry. This hypochlorite is produced by passing chlorine into a cold solution of potassium carbonate, and the resulting solution contains a mixture of chloride, hypochlorite and hypochlorous acid. The reaction takes place in two stages. First, chloride and hypochlorite of

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[28] Journal of the Society of Chemical Industry, XXII (1903), p. 92.
[29] Journal of the Society of Chemical Industry, XXIV (1905), p. 25.

potassium are formed, carbon dioxide being liberated.

$$K_2CO_3 + Cl_2 \longrightarrow KOCl + KCl + CO_2.$$

The carbon dioxide does not escape at first. As long as any normal potassium carbonate is present, this is converted by the carbon dioxide into bicarbonate.

$$K_2CO_3 + CO_2 + H_2O \longrightarrow 2KHCO_3.$$

When all the carbonate is present as bicarbonate, the chlorine decomposes this, forming hypochlorous acid and liberating carbon dioxide, which now escapes. Thus, effervescence marks the beginning of this stage,

$$KHCO_3 + Cl_2 \longrightarrow HOCl + KCl + CO_2$$

or, if the excess chlorine be used

$$K_2CO_3 + H_2O + 2Cl_2 \longrightarrow 2KCl + 2HOCl + CO_2.$$

A solution containing free hypochlorous acid would be comparatively unstable. Hence, the reaction is stopped as soon as free carbon dioxide is liberated, and a little normal carbonate is added to make the solution alkaline.

A similar solution for bleaching purposes may be prepared by using sodium carbonate, or milk of lime. However, sodium and potassium hypochlorite solutions cannot be stocked for very long periods of time.

Sodium and potassium hypochlorite solutions, even though more expensive than calcium hypochlorite, are desirable because they do not precipitate any water insoluble salts on the goods as is the case with the calcium compound. A good efficient solution of sodium hypochlorite may be prepared by adding sodium carbonate in excess to a fresh solution of

bleaching powder. The sodium hypochlorite is formed by double decomposition and the salts of calcium carbonate precipitated, thus

$$Ca(OCl)_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2NaOCl.$$

Hypochlorites when treated with strong acids will yield hypochlorous acid or free chlorine depending on the amount of acid used. On the other hand, the addition of alkalis to hypochlorite solutions will neutralize the free hypochlorous acid and further hydrolysis will be retarded or inhibited. If neutral salts are mixed with a hypochlorite solution, they will break the equilibrium of the solution. In order to reestablish a condition of equilibrium once again, free chlorine is generated. The action of metals and their oxides on hypochlorite solutions is that of a catalyst or oxygen carrier. Hypochlorite solutions will liberate the whole of their oxygen when metals or their oxides are present.[30] When the temperature of the hypochlorite liquor is too low as to give a satisfactory, fast and efficient bleach, it has been found that the bleaching action can be accelerated by light, ultraviolet being the effective rays.[31]

The bleaching action of hypochlorites has been the subject of much discussion and speculation.[32] Taylor states that the free chlorine is the active bleaching agent and that hypochlorous acid plays only a minor part in bleaching.

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[30] Trotman, S. R., "The Bleaching, Dyeing, and Chemical Technology of Textile Fibers", p. 276 - 278, Charles Griffin & Company, Limited, London, 1925.

[31] "Ultraviolet, an Aid to Bleaching", Textile Colorist, LVIII (1936), p. 463.

[32] Higgins, S. H., "Bleaching", p. 54, Longmans, Green & Co., London, 1921.

Higgins,[33] however, states that the bleaching action of hypochlorites is due to the direct generation of oxygen and the generation of nascent chlorine to some extent at the beginning of the action. Sun rays stimulate the bleaching action of hypochlorites; this increased efficiency forms a parallel with decreased stability and points to the conclusion that the pure oxygen which is involved performs the bleaching. Matthews[34] points out that the bleaching agent in hypochlorite solutions is chlorine in a loosely combined condition. In the process the chlorine is liberated in the nascent state in the presence of water; the latter is decomposed by the chlorine yielding hydrochloric acid and nascent oxygen, and it is this oxygen which causes the bleaching action.

McMyn and Bardsley[35] state that the carbon dioxide in the air considerably assists the bleaching action by liberating the much more active substance hypochlorous acid. They, too, consider the hypochlorous acid as the bleaching agent. Kauffmann,[36]

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33 Higgins, S. H., "Bleaching", p. 54-58, Longmans, Green & Co., London, 1921.

34 Matthews, J. M., "Application of Dyestuffs", p. 116-117, John Wiley & Sons, Inc., New York, 1920.

35 McMyn, J. W. and Bardeley, J. W., "Bleaching, Dyeing, Printing and Finishing", p. 58, Sir Isaac Pitman & Sons, Ltd., London, 1932.

36 Kauffmann, H., "Kinetics of Chlorine Bleaching", Journal of the Society of Dyers and Colorists, XLVI (1930), p. 414.

basing himself on the fact that a hypochlorite solution will bleach at a speed which is inversely proportional to its alkali content and directly proportional to its neutral salt contant, deducts that free hypochlorous acid is the bleaching agent. Later on the same author arrived at the conclusion that two substances are necessary for the bleaching effect, one of which is a true oxidizing agent and the second of which he calls an activator.[37] In a hypochlorite bleaching liquor the oxidizing substance is the hypochlorite ion and the activator is the free hypochlorous acid. With this new theory, Dr. Kauffmann has revolutionized the generally accepted theory of nascent oxygen by itself. According to his conclusions, the efficiency of a hypochlorite solution depends to a great extent on the concentration of the activator present.[38] Hampson accepts this new hypothesis and goes into proving it by his own experimental work, pointing out also that the action of hypochlorite solutions can be regulated by controlling the concentration of activator in solution.

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[37] Kauffmann, H., "The Latest Research Work on Cotton Bleaching", American Dyestuff Reporter, XXI (1932), p. 647-649.

[38] Hampson, C. G., "The Chemistry of Cotton Bleaching", Textile Colorist, LX (1938), p. 700-703.

V. MANUFACTURE OF BLEACHING POWDERS AND BLEACHING SOLUTIONS IN COMMERCIAL PRACTICE

Since the discovery of bleaching powder by Tennant at the beginning of the nineteenth century, the production of this substance has been the subject of intensive research. Although the basic reactions are all the same, the details of the processes vary to some extent.

Commercially, bleaching powder is manufactured by exposing slaked lime to the action of chlorine gas. The slaked lime is spread on the floor of a specially constructed chamber and the chlorine is led in through an opening at the top under a slight pressure. A glass window is provided through which the progress of the absorption can be observed. As soon as the yellow color of the chlorine disappears, more is introduced. This is repeated, the lime being also turned occasionally, until no more chlorine is absorbed, indicated by the permanent color of the gas in the chamber. Some fresh slaked lime is then added to absorb the residual chlorine and, after this, the powder is removed and packed in air-tight drums. The temperature of the operation must be kept low or calcium chlorate will be produced. Good commercial samples produced by this process contain from 35 to 38 percent of active chlorine or available chlorine as it is generally termed.

However, many variations of this process have been introduced and in each case they are claimed to be definite

improvements. The truth of the matter is that bleaching powders can be produced by many commercial processes and all will give satisfactory results.

MacMillan and Taylor[39] use the following method. The addition of sodium chloride to a saturated calcium hypochlorite solution at about 16 degrees centigrade results in the separation of crystals of a triple salt, $Ca(OCl)_2.NaOCl.NaCl.12H_2O$ which may be employed for bleaching. A stable calcium hypochlorite is produced by the addition of sufficient calcium chloride to the triple salt at low temperature to react with the sodium salt. A solution of caustic soda and calcium hydroxide, saturated with respect to the sodium chloride and the triple salt, is chlorinated under conditions such that common salt only crystallizes out, the triple salt being obtained from the supernatant liquor. A further modification is given by the authors. The triple salt may be produced by adding sodium chloride at 0 degrees centigrade to a chlorinated lime solution containing calcium chloride and hypochlorite but free from hydrated calcium hypochlorite.

C. Carter, of the Imperial Chemical Industries, LTd.,[40] introduced another method. A large volume of dilute chlorine gas is circulated, in couter current, with slaked lime or

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39 MacMillan, R. B. and Taylor, M. C., "Hypochlorite Compositions", Journal of the Society of Dyers and Colorists, XLVI (1930), p. 352.

40 Imperial Chemical Industries, Ltd. and Carter, C., "Bleaching Powder", Journal of the Society of Dyers and Colorists, XLVII (1931), p. 174.

partially slaked lime kept agitated in a rotary tube. A spray of water is introduced during the process to control the temperature and prevent premature drying of the material in the chlorinating zone. A greater output of ordinary bleaching powder is obtained by using dry chlorine or partially dry chlorine and adjusting the volume in circulation. A tropical product, i.e., a product of high strength and low moisture content, is obtained in a single operation by using hot chlorine.

I. G. Farbenindustrie A.[41] produces a stable bleaching powder by suddenly bringing it, in a very fine state of division, in contact with a current of hot air (160 degrees to 180 degrees centigrade) following in the same direction for a few seconds only. This same company claims that a very stable bleaching powder containing 36 percent or more of available chlorine may be produced as follows.[42] A commercial product of the desired chlorine value is mixed with one-half to one part of unslaked lime for each part of the total water content and the mixture is exposed to conditions of temperature leading to slaking of the lime. Finally, the product is freed from water by treatment with a current of warm air. A third process is given as follows by the same concern.[43] To avoid the wet point

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[41] I.G. Farbenindustrie A. - G., "Stable Bleaching Powder", Journal of the Society of Dyers and Colorists, XLVII (1931), p. 267.

[42] I.G. Farbenindustrie A. - G., "Storage-proof Bleaching Powder", Journal of the Society of Dyers and Colorists", XLVII (1931), p. 267.

[43] I.G. Farbenindustrie A. - G., "Bleaching Powder", Journal of the Society of Dyers and Colorists, XLIX, (1933), p. 332.

in the making of bleaching powder, chlorination is stopped on reaching a chlorine concentration of about 30 to 32 percent. Then the resultant substance is dehydrated and mixed with enough of an anhydrous calcium hypochlorite compound to give a product of any desired chlorine concentration. The product is extremely stable.

Hypochlorite solutions from bleaching powder are prepared by simply dissolving the solid powder in water in such proportions as to give the desired concentration of chlorine in the stock solution. During the addition of the bleaching powder to the water, considerable agitation is needed. After the addition of the calcium compound is completed, the solution is allowed to stand so that the insoluble impurities will settle down from suspension.

Sodium or potassium hypochlorite solutions can be produced by passing chlorine gas through a sodium or potassium carbonate solution.[44] Ullman gives a method for producing sodium hypochlorite by the action of chlorine gas on a solution of caustic soda, making sure that an excess of alkali is present to insure stability of the solution.[45] Ivey points out the convenience of using both sodium hydroxide and carbonate in the preparation of bleaching solutions from chlorine gas. The hydroxide will form the stable compound, while the carbonate gives

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[44] Ullman, G., "Bleaching Solutions and Chlorines and Their Self Production", Textile Colorist, LXV, (1943), p. 227, 231, 253, 273.

[45] Ivey, J. W., "The Use of Chlorine in Bleaching Cotton Goods", American Dyestuff Reporter, XIX (1930), p. 611-616.

the necessary excess of alkali. The author claims that this procedure gives a solution that is stable enough to be carried in stock for several days, and, then, when used, the bleaching action will be faster than when using straight caustic soda. Savell and Ivey,[46] of Mathison Alkali Works, mention the fact that sodium hypochlorite solutions of very high chlorine content can be prepared by the action of sodium carbonate on a fresh solution of H.T.H. Here also the alkali must be present in a slight excess.

Jacquemain and Doll[47] emphasize the fact that sodium hypochlorite solutions should not be kept in stock over long periods of time. They also point out that if stock solutions are to be kept for several days, they should be in dark, cool places to prevent the decomposition and loss in strength of the product.

A method used to a certain extent in the production of sodium hypochlorite solutions is by the electrolysis of sodium chloride. This is an application in the bleach house of the methods used for the commercial production of caustic soda and chlorine from sodium chloride. An English patent was taken out by Haas and Oettle.[48] The process consists in placing

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[46] Savell, W.L. and Ivey, J.W., "Use and Misuse of Chlorine in Textile Bleaching", American Dyestuff Reporter, XX (1931) p. 97-100.

[47] Jacquemain, R. P. and Doll, J. H., "Influence of Time, Light and Temperature on the Storage of Eau De Javelle", Journal of the Society of Dyers and Colorists, LII (1936), p. 97.

[48] Bean, P., "The Chemistry and Practice of Finishing", Vol. I, p. 158-160, Hutton, Hartley & Co., Ltd., Manchester, 1926.

the sodium chloride solution in a tank until it is nearly full, then the electric current is passed through. In the center of the tank is the electrolyzer on either side of which are placed cooling coils. It is necessary to keep the liquor cool, otherwise, sodium chlorate will be produced instead of sodium hypochlorite. The temperature should not be allowed to rise above 86 degrees fahrenheit. The brine solution is decomposed by the action of the electric current into its constituents, sodium and chlorine. The chlorine is liberated at the positive pole and the sodium of the negative pole. The sodium immediately combines with water, to form caustic soda, with the evolution of hydrogen. The chlorine unites with the sodium hydroxide to form sodium hypochlorite. The current is passed through the brine solution until a solution of sufficient strength of available chlorine is obtained; the liquor is then removed from the electrolyser tank and placed in the bleaching vat. The amount of chlorine available in solutions of sodium hypochlorite thus produced cannot be ascertained by means of their specific gravity, and, therefore, titration methods have to be used. Some of the advantages claimed for the electrolytic method are its cheapness and its freedom from sediment. However, such solutions are decomposed very quickly and do not lend themselves to all bleaching procedures due to their low chlorine contents.

VI. STANDARD METHODS OF HYPOCHLORITE BLEACH

The bleaching of cotton goods involves two main points. First, the removal of all soluble matters by means of a thorough treatment with alkalis and acids and washing. Second, the removal of the insoluble coloring matter remaining after the first treatment by means of a true bleaching agent. Bleaching, unfortunately, is subject to many opinions and no one method can be given as standard. The bleacher himself and his convictions play a great part in the selection of the best suited bleaching method to be used in the processing of a given lot of goods. The factors contributing to the decision of the bleacher are the grade of the goods, the weight of the materials, the amount of natural and added impurities present and the purpose for which the goods are intended.

In spite of all the variables involved, the bleaching process is made up of cartain operations which are standard and which are the units, so to speak, of the general procedure employed. The different methods of bleaching are nothing but a combination, in one way or another, of these basic operations. The operations are singeing, desizing or steeping, kier boiling, souring, chemicking, anthichlor and washing.

1. Singeing. This name is given to the operation by means of which the nap or fuzz of the fabric is removed from the face of the cloth. This is accomplished either by passing

the cloth rapidly over the surface of strongly-heated copper plates or rollers, plate singeing, or by giving it a passage through a non-luminous gas flame, gas singeing.

In plate singeing, the nap is chiefly removed from the surface of the cloth, while in gas singeing the flame, penetrating more or less into and through the cloth, removes the loose fibers in the interior of the fabric. Thus, by the latter method, the cloth is much more thoroughly singed than by the former. Such a thorough singeing may in some cases not be required and both types of singeing machines are, therefore, frequently found working side by side.[49] Steevens emphasized the fact that if the warp yarns used in the manufacture of the cloth have been sized with mixtures containing such substances as magnesium chloride, they must be removed preparatory to the singeing by washing with water and drying, as the heat of the singeing would decompose the chlorides, setting free hydrochloric acid which would rapidly tender the fabric by attacking the cotton.[50]

2. Desizing or steeping. By means of this process it is aimed to remove as much as possible of the soluble impurities present in the goods before the kier boiling. Bothamley[51] brings out the fact that starches will produce a gum-like

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49 Hubner, J., "Bleaching and Dyeing of Vegetable Fibrous Materials", p. 86-89, Constable & Company, Ltd., London (1927).

50 Steven, A.B., "Textile Bleaching", p. 42-45, Sir Isaac Pitman & Sons, Ltd., London (1934).

51 Bothamley, J., "Kier Boiling", American Dyestuff Reporter, XXIII (1934), p. 350-351.

substance in the presence of alkalis. This will cause the kier liquor to become heavy and syrupy and, thus, interfere with the proper circulation of the kier liquor.

This process is used in several ways. Some bleachers steep the goods in warm water over night, or until natural fermentation is set in and the starches are converted into dextrose, and the cotton proteins partly dissolved as peptones. Heavily sized goods are treated with diastase in order to remove the starch. There are several commercial preparations of enzymes such as Exsize. About one percent of enzyme compound, on the weight of the goods, is dissolved in water and the fabric is either impregnated with this solution at 65 degrees centigrade and allowed to stand for some time, or it is soaked in the liquor until the starch is completely converted to its soluble form.[52] Rohm and Haas have produced Diastase on a commercial basis, which is a solution of standarized amylolitic enzyme and it is claimed that fabrics are digested with as low as one-tenth of one percent solution. A third method of steeping the goods before kier boiling is by treating them in a dilute solution of hydrochloric or sulphuric acid. This acid treatment is claimed to solublilize a great percentage of the added impurities and to attack the protein and pectic contents of the cotton fiber. Some other bleachers use a combination of two of the above treatments in order to get better preparation of the goods before the kier boil.

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52 Rohm and Haas, "Diastaze", Technical Bulletin, (1937).

The tendency today is toward shorter and more efficient steeping treatments at lower costs. The introduction of enzymes is regarded as quite an improvement in time saving. At any rate, a good steeping of the goods previous to kier boiling will improve the efficiency of the kier and of the chemicals used.

3. Kier boiling. This is the most important part in bleaching, and the results obtained at the end will largely depend on the thoroughness of this treatment. Essentially, it consists in boiling the goods under pressure for several hours with an alkali and some assistant. At first, it was done in open vessels, and it is as old as the bleaching industry. Due to its importance, this action has been the topic of much research and discussion.

The boiling of the goods can be done in open kiers or pressure or closed kiers. However, the open kier has left the field open to the pressure kier in most cases due to the high cost of operating it and the extra time required for obtaining the desired results. Nevertheless, the open kier finds its use when the materials to be treated contain some yarns dyed with colors which may be affected by pressure and high boiling temperatures.

The first pressure kiers were large closed vessels where the goods were evenly piled and packed. The liquor was circulated and heated by injection of live steam. The pressure was built by the steam itself. This method of circulating the liquor was very inefficient since, when the proper temperature

was obtained, the steam was cut off, eliminating the circulation. The use of live steam also caused the kier liquor to be diluted to quite some extent in the course of the boil, and, thus, a great deal of kier efficiency was lost.

The modern kiers, such as the Allen Patent Worcester,[53] eliminate the fault of the injector by using a centrifugal pump to circulate the liquor. It also eliminates the use of steam for heating the bath by the use of a superheater. This kier also presents the feature of reversible circulation from top to bottom or vice versa. Also, the pressure obtainable in this type of kier is higher and more uniform, thus, insuring greater efficiency and increased uniformity of results.

Before the goods are entered in to the kier, it is advisable to give the walls of the kier and all metal parts that come in contact with the material a white wash to prevent the damaging of the goods. If the kier is new, it should be first coated with a thin layer of cement and then white washed with lime. Some bleachers prefer to coat the kiers with sodium silicate to produce a glass effect, but, whichever method is used, the main point to be kept in mind is that the goods should not come in contact with any metals in the kier boiling process.

When the goods have previously been steeped, they are thoroughly washed and then squeezed and packed in the kier. The packing of the goods can be accomplished either by hand or by mechanical means. Once the goods are well packed in the kier,

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53 Hughes, T. F., "Bleaching Cotton Piece Goods in One Boil", American Dyestuff Reporter, XIX (1930), p. 455-458.

it is filled half with water and then the alkali charge is run in, finally, adding more water until the goods are floated. With the manhole open, the circulation is started to make sure that the goods are properly packed and that there is no defective or clogged circulation. When this has been checked and found satisfactory, the manhole is closed and the heating is started. The vent pipe valve is left open until the boiling point is reached to allow all the air present to leave the kier. When the kier starts boiling, the vent is closed. Pressure should not be allowed to build up if all the air has not been removed.

The alkali charge, the temperature used, the required pressure, the kier assistants, the length of kier treatment, and the number of kier boils are subjects of wide variations. The old lime boil,[54] as given by McMyn and Bardsley, consisted in impregnating the goods with a solution of milk of lime of such strength that three to four percent of actual lime content would be absorbed. The goods were then piled in the kier, and the kier was filled with water. The boil was carried for six to ten hours at about twenty pounds of pressure. After this length of time, the liquor was run off and the kier was filled up with cold water to prevent damage of the goods. According to Holmes the fats in the goods are converted into insoluble calcium salts and the pectoses and pectins into insoluble pectates of calcium.[55] These insoluble salts are

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54 McMyn, J. W. and Bardsley, J. W., "Bleaching", Dyeing, Printing, and Finishing", p. 52-55, Sir Isaac Pitman & Sons, Ltd., London, 1932.

55 Holmes, J. F., "The Boiling and Bleaching of Cotton", Textile Colorist, LVI (1934), p. 53, 60.

removed upon further souring and lye boiling of the goods.
Estey[56] gives the following procedure for a lye boil. The lye charge should stand at four degrees Twaddle after the caustic soda and soda ash have been added. The addition of a good kier oil is desirable to give penetration and also bisulphite of soda should be added to help expel the air from the kier. After a nine hour boil at a pressure of twenty pounds, the detergents in the kier should be exhausted. Holmes[57] gives a general formula for lye boils as follows: Ten grams per liter of caustic soda, five grams per liter of soda ash, one to two grams per liter of resin and five to ten mililiters per liter of sodium bisulphite of seventy-seven degrees Twaddle. The duration of the boil should be from six to eight hours and the pressure twenty-nine pounds and not above thirty-seven pounds. Bothamley[58] advises the use of three percent caustic soda and two percent kier assistant. Ten hours' boil is used at a pressure ranging from twenty to thirty pounds. Tagliani[59] recommends the use of only one boil at low pressure with caustic soda, sodium carbonate or silicate, or lime and soda. Boiling should not be carried over long periods of time, and he sets four hours as the limit.

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[56] Estey, A. C. "Improvements Made in Bleaching", Textile Colorist, LIV (1932), p. 455-456.

[57] Holmes, J. F., "The Boiling and Bleaching of Cotton", Textile Colorist, LVI (1934), p. 53-60.

[58] Bothamley, J., "Kier Boiling", American Dyestuff Reporter, XXIII (1934), p. 350-351.

[59] Tagliani, G., "Protection of Vegetable Fibers During Bleaching", Journal of the Society of Dyers and Colorists, LIV (1938), p. 39-40.

Hampson[60] gives the following one kier boil method of bleaching. He recommends the use of two percent caustic and one percent kier assistant at a temperature of not more than 120 degrees centigrade and at not over thirty pounds of pressure for about nine to ten hours. Scholelield and Ward[61] use two percent caustic soda and 0.2 percent of Lissapol A, a sulphonated alcohol type of kier assistant, at a boil for seven and a half hours and with twenty pounds of pressure.

The scouring of goods is carried out not only in kiers but also in jigs. When the treatment required is only that of removing the majority of the impurities on the goods without aiming at the destruction of the coloring matter, the jig will give very good results in about four to six ends at a boil or near a boil with three percent of caustic soda and one-half of one percent of a good penetrant.

However, a great deal of research has been carried out aiming to reduce the length of time needed in the bottoming of the goods before bleaching. The Russian chemists Filopov and Voronkov[62] have been able to accomplish a great reduction in the time and cost of scouring. They do away with the conventional kier and introduce a method of scouring that will lend itself to

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60 Hampson, C. G., "The Chemistry of Cotton Bleaching", Textile Colorist, LX (1938), p. 700-703.

61 Scholefield, F. and Ward, D., "Some Observations on Kier Boiling Efficiency", Journal of the Society of Dyers and Colorists, LI (1935), p. 172-178.

62 Hall, A. J., "Comparison of a Modern U.S.S.R. Kiering and Bleaching Process with the Usual Wester Methods", American Dyestuff Reporter, XXII (1933), p. 1-4.

the use of continuous hypochlorite bleaching with very satisfactory results. Filopov and Voronkov scour the fabrics without previous treatment at all by heating them for thirty to forty minutes in open vessels at 85 degrees to 95 degrees centigrade in a liquor containing two and one-half percent caustic soda, an emulsifier, sodium silicate, and sodium or potassium sulphite.

E. I. du Pont de Nemours and Company[63] have introduced the following method of scouring cotton goods. The goods are first wetted with aqueous alkali containing about six percent by weight of caustic soda. They are then passed through a steaming compartment maintained at 83 to 93 degrees centigrade, where they are kept long enough for the alkali to produce the desired effect, generally forty-five minutes to one hour.

Vincent, Dubeau, Synan, Carr, Fenrich and Dingers, of the Mathison Alkali Works, Inc., have developed a new process of scouring cotton goods.[64] The goods are treated in full width and travel continuously through a hot padder containing the scouring solution which is made up of four to eight percent caustic soda, one-half of one percent synthetic detergent, 0.1 percent penetrant, 0.15 to 0.25 percent Textone. No previous steeping is used. Traveling through the padder at the rate of 100 yards per minute, the fabric is impregnated with the hot solution and passed through rolls

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[63] Du Pont, "Treatment of Textile Materials", Journal of the Society of Dyers and Colorists, LVII (1942), p. 131.

[64] Vincent, G. P., Dubeau, A. L., Synan, J. F., Carr, R. L., Fenrich, E. G., and Dinges, H. R., "Elimination of Kier or Jig Scouring by Alkaline Steaming", American Dyestuff Reporter, XXXIII (1944), p. 536-538.

which remove the surplus liquid. The goods are then drawn into the steamer, which is kept full of steam at atmospheric pressure while in operation. But before reaching a slowly moving conveyor, which travels at the rate of two feet per minute, the fabric passes in front of a row of steam jets issuing from a perforated pipe which cause it to billow outwards and to fall on the belt in loose folds, forming a continuous pile about a foot high. At the end of its travel in the steamer, the fabric is removed from the belt, also at the rate of 100 yards per minute, and given a water wash. By adjusting the proper belt speed, a treatment of about thirty minutes is given to the cloth in the steam chamber. The length of steaming will determine the degree of scouring obtained on the goods.

4. Souring. This is a process used in connection with the lime boil and calcium hypochlorite chemicking. The goods are treated in a weak solution of mineral acid, hydrochloric preferably, for fifteen or thirty minutes cold or luke warm. A concentration of one-half to one percent will be satisfactory for all practical purposes. The acid decomposes the lime soaps, removing the calcium portion and leaving the free fatty acids on the cloth to be removed by the soda in the next scouring operation. In the case of the calcium hypochlorite treatment, the acid will decompose the calcium carbonates into the soluble chlorides of calcium, and it will also free the goods from any chlorine left on them. The soured goods have to be thoroughly washed before going into the next process, otherwise, the whole purpose of the sour would be defeated.

5. Chemicking. Fundamentally chemicking consists in the treatment of the scoured goods with the hypochlorite bleaching agent. This is accomplished in specially built cisterns without any ordinary metal parts. Wood, concrete, and stone are the most used materials in the manufacture of such vessels. However, with the introduction of stainless steel, bleaching vats are now being made out of this material.

Chemicking is generally accomplished by one of two methods. Either the goods are soaked in the cold bleaching liquor until the desired degree of whiteness is obtained, or they are impregnated with the cold hypochlorite solution and then piled in bins until the bleaching is complete. Here, again, the concentration of the hypochlorite solution, the temperature used, and the length of time of treatment are the subject of much discussion. Some bleachers may select one set of conditions, while others would select another set of conditions entirely different. The truth of the matter is that the condition in which the goods reach the chemicking process will control to a great extent the kind of treatment to be adopted.

Filopov and Voronkov[65] claim to have obtained good bleaches by treating the scoured goods for thirty minutes in a calcium hypochlorite solution of one-half to one degree Twaddle.

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65 Hall, A. J., "Comparison of a Modern U.S.S.R. Kiering and Bleaching Process with the Usual Western Methods", American Dyestuff Reporter, XXII (1933), p. 1-4.

Bothamley[66] uses a hypochlorite solution of one-half of one degree Twaddle for forty-five minutes to one hour to obtain good results. Schwalbe and Wenzel[67] recommend the use of a solution of sodium hypochlorite containing twenty grams of available chlorine per liter where the goods are steeped for five minutes at 30 degrees to 40 degrees centigrade. They recommend this quick bleaching method for open width treatment of fabrics and emphasize the necessity of very good washing after the chemicking. Goble[68] makes the following statement. Addition of sodium bicarbonate to calcium hypochlorite baths has a favorable influence on their bleaching action, but increases the consumption of chlorine, and on prolonged treatment, causes marked tendering of the fiber. Its use is recommended, however, in the rapid bleaching process, the duration of which does not exceed ten minutes, provided that the bleached goods are rinsed immediately.

Kauffmann[69] recommends the use of a distinctly acid hypochlorite bath, followed by one of hot hydrogen peroxide, both on the grounds of rapidity of action and preservation of

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[66] Bothamley, J., "Kier Boiling", American Dyestuff Reporter, XXIII (1934), p. 350-351.

[67] Schwable, C. G. and Wenzel, H., "Development of the Rapid or Concentrated Bleaching Process", Journal of the Society of Dyers and Colorists, LI (1935), p. 430-431.

[68] Goble, E. F., "American of Sodium Bicarbonate in Calcium Hypochlorite Bleaching Baths", Journal of the Society of Dyers and Colorists, LIV (1938), p. 243.

[69] Kauffmann, H., "Kinetics of Chlorine Bleach", Journal of the Society of Dyers and Colorists, XLVI (1930), p. 414.

fiber strength. H. Tk. Bohme, A. G., Cheminitz,[70] treat cotton goods with hypochlorite bleaching solution long enough for the fibers to become completely saturated, then, without rinsing or antichloring, subject them to an alkaline perioxide bleach liquor. They claim to be able to obtain very satisfactory whites without cellulose degradation.

6. Antichloring. This operation consists in removing all the free chlorine remaining in the goods after chemicking. Sodium hyposulphite, sodium sulphite, sodium bisulphite and sulfur dioxide are some of the most common agents used. They all produce sodium chloride and hydrochloric acid with the free chlorine present, thus, making possible to remove it from the fiber by washing.

Alling[71] recommends the use of sulfur dioxide on the grounds that it is more efficient than any other product used and that it is used in very small quantities. The sulphur dioxide will produce sulfurous acid with the water, and the sulfurous acid upon reacting with the oxygen present will be converted to sulfuric acid. The sulfuric acid will neutralize all the alkali present and convert the chlorine to the chloride of the alkali used in the making of the hypochlorite solution.

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70 Pettinger, A. H., "Recent Research and Developments in Bleaching Technique", Textile Colorist, LVII (1935), p. 317-319.

71 Alling, M.W., "Kier Boiling, Peroxide and Sodium Hypochlorite Bleaching, and Antichloring Cellulose Fabrics", American Dyestuff Reporter, XXII (1938), p. 544-546, 558.

Sulfuric and hydrochloric acids are also used for this purpose. The concentrations commonly used vary from one-half of one percent to one percent. The acids will eliminate the chlorine from the fiber at the same time that they neutralize any alkali present or will convert the calcium carbonates into the soluble calcium chlorides or the less soluble calcium sulfates.

7. Washing. The washing of the goods during the bleaching process is one of the most important factors controlling the quality of the results obtained. The materials should be thoroughly washed after every operation before going to the next in order to remove all the impurities made soluble by the chemical treatments. If the goods are finished without a good wash, the chemicals left in the fiber may cause tendering, and the white produced could be stained on storage.

For the washing of the goods, large quantities of fresh water are used. Therefore, it is important that the quality of water used should be suitable for the requirements of the bleach house. The softness of the water should be a matter of much attention, especially for the kier boils and washes. If the water used is of undue hardness, chances are that the goods will be stained and that they will have a harsh feel if they are not soured more than what would be necessary under normal conditions.

Suspended matter invisible to the naked eye will precipitate on the goods during washing if such substances are not removed before the water reaches the kiers and wash vessels.

Spore forming bacteria, if present in the water, will produce stains, peculiar odors and mould on the goods upon storage. Water of high iron contents will produce stains which are very hard to remove. Likewise, trouble from matalic oxides may be expected from the piping if the water has a low pH value. Blackwelder[72] gives many good points in the treatment of water for use in textile finishing processes, and he emphasizes the value of good water as savings to the industry.

At the beginning of this chapter it was stated that these individual processes are combined in several ways by the bleachers to obtain the desired degree of cotton purification. Some of these processes are repeated several times before the results are considered satisfactory, while in some other cases satisfactory results are obtained without using every single operation described. The most thorough bleaching treatment given in industry is the Madder bleach. This treatment consists of: Singe, Steep, wash, lime boil, wash, sour, wash, lye boil, wash, sour, wash, lye boil, wash, chemick, wash, sour and final wash. It is a long drawn out process, but it will produce perfect whites, and, if the proper control is used, it will produce very little cellulose degradation.

Another method used for obtaining very good results is the Caustic Soda bleach. The goods are given in this treatment, after singeing, steeping, and washing, a caustic kier boil, a wash, a lye boil, a wash, a chemicking, a wash, a sour, a wash,

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72 Blackwelder, C. D., "The Treatment of Water for Bleaching and Dyeing", Textile Colorist, LII (1930), p. 769-770.

a boil with soda ash at ordinary pressure, a wash, another chemicking, another wash, another sour and a final wash.

A good commercial bleach is obtained by singeing, steeping or desizing and washing, then kier boiling with caustic and assistant, washing again and chemicking after which the goods are antichlored and given the final wash.

The Madder bleach and the Caustic Soda bleach are designed in this case for heavy fabrics. They represent the best in bleaching of goods, and they cannot be very well performed without a certain amount of skill. The commercial bleach, however, gives satisfactory results for all practical purposes, and it is used when the goods are to be sold white. Sometimes, the white is improved by a tinting or bluing, and the feel of the fabric can be made softer by a soaping operation before drying and finishing or by the use of some finishing oil.

VII. OTHER METHODS OF BLEACHING

Hypochlorite solutions are used in bleaching because they are cheap and render satisfactory results. Nevertheless, attempts have been made to find other products that will also have a bleaching action. The main requirement for any product to be used as a bleaching agent is that it should generate oxygen without deteriorating the goods and also should be economical.

Among the early products to be used as bleaching agents, other than hypochlorites, were potassium permanganate, sodium perborate, and the peroxides. All these compounds will generate oxygen, and the oxygen generated will oxidize the coloring matter present in the fiber. They are more expensive than the hypochlorites and cannot compete with them. The reason for the high cost of bleaching with these products is not only their higher original cost but the high cost of the chemicals used to assist the bleaching and the increased handling of the goods. However, it is interesting to study these processes as they are used and the chemistry they involve.

1. Permanganate bleaching. The goods have to be scoured before they can be given a good bleach with the action of permanganate solutions. After scouring, the material is steeped in a cold solution of potassium permanganate of about one-half of one percent. This solution has to be acidified,

and sulfuric acid is the agent most widely used. The permanganate gives up its oxygen and thereby becomes reduced to a hydrated oxide of manganese which is precipitated on the fiber as a dark brown deposit. To remove this brown precipitate of manganese requires the rinse of the cotton in water and the passage of the goods into a fresh bath of a diluted solution of sodium bisulphite. The goods are treated with permanganate for about ten minutes, and then they are washed and treated with the bisulphite for another ten minutes. Unfortunately, good whites cannot be obtained with just one such treatment and the process has to be repeated several times. By using an excess of sulfuric acid in the permanganate solution, the bisulphite treatment can be neglected, since the acid will prevent the formation of the manganese oxide. However, such an increase in the concentration of sulfuric acid may be detrimental to the cotton goods.

The bleaching effect of a permanganate solution differs considerably depending on whether the solution is acid or neutral. In the former case, five atoms of oxygen are available, whereas in the latter case only three atoms of oxygen are set free. But whichever method may be used, the rapidity of the bleach obtained does not allow a well penetrated bleach with the consequence that the inner parts of the fiber are not properly bleached, and, though the surface may at first appear quite white, this superficial purity is liable to be lost after a time. This is specially true if al l traces of the manganese compounds are not thoroughly washed out.

Holmes[73] claims to have obtained a satisfactory bleach by treating the goods with a solution of half of one percent of sulfuric acid and from 0.2 to five percent of permanganate. The material is soaked for about three hours in this solution, removed and washed. The oxides of manganese are dissolved by the action of a weak bath of sulfuric acid after which a thorough wash completes the process.

2. Perborate bleaching. The bleaching agent when perborates are used is hydorgen peroxide. When sodium perborate is dissolved in water it decomposes into caustic soda, borax and hydrogen peroxide. This gives an alkaline solution, but more caustic has to be added to produce a good bleach. This method is too expensive for industrial purposes, and the results obtained are no better than the results of a hypochlorite bleach. However, it is claimed that the action of the perborates on the cotton is very mild, and, therefore, no great deterioration of the goods takes place.

Matthews[74] gives the following procedure for bleaching cotton goods with sodium perborate. The fabric is first desized and then well rinsed. Scouring is unnecessary except in the case of very dirty goods. The pieces are then steeped

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73 Holmes, J.F., "The Boiling and Bleaching of Cotton", Textile Colorist, LVI (1934), p.53,60.

74 Matthews, J.M. "Bleaching and Related Processes", p.376-377. The Chemical Catalog Company, Inc., New York, 1921.

in the bleach liquor until saturated and then heated in the caustic soda lye for four to five hours while the whole liquor is circulated under a pressure of twenty-two to thirty pounds. The bleach-lye liquor is made up of a five percent solution of caustic soda, two and one-half percent soap, one and one-fourth percent sulphonated oil, three-fourths of one percent of sodium perborate, and three-fourths of one percent of sulphate of alumina. The goods are afterwards removed, washed well and finished.

3. Peroxide bleaching. This method of bleaching cotton goods was first used with the aid of sodium peroxide which in solution produces sodium hydroxide and hydrogen peroxide, the active bleaching agent. The goods have to be thoroughly scoured before they are submitted to the bleaching action of the peroxide.

Bottler[75] gives the following procedure for bleaching with sodium peroxide without previously kier boiling the material. The bleaching liquor is prepared by mixing eight parts of caustic soda, one part of sodium silicate and one part of sodium peroxide. One part of this mixture is dissolved, slowly and in small portions, in 150 parts of cold water. The resulting liquor is poured over twenty-five parts, by weight, of goods in a kier, which is then filled up with water, closed and gently warmed for three to four hours. This causes a gradual liberation of oxygen from the peroxide, the impurities

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75 Bottler, M., "Modern Bleaching Agents and Detergents", p.20, Scott, Greenwood & Son, London, 1910.

in the fiber being thereby oxidized and bleached, whilst the alkali saponifies any fatty matter present.

However,[76] Hubner recommends the scouring of the goods with a thorough kier boil before bleaching. The bleaching solution is prepared by dissolving thirty pounds of magnesium sulphate in ninety-five gallons of water, then adding ten pounds of sodium peroxide and twelve and one-half pounds of sulfuric acid. One hundred pounds of material are bleached at 100 degrees to 115 degrees Fahrenheit for one to ten hours. After bleaching, the goods are soured in a dilute solution of sulfuric acid and thoroughly washed.

With the new developments in the manufacture of commercial hydrogen peroxide and the lower cost of this product, its use as a bleaching agent for cotton has increased. One of the main objections to the use of hydrogen peroxide for bleaching was its high cost. The use of straight hydrogen peroxide eliminates the dangers of handling the sodium peroxide and its fire hazard. Besides, the treatment is milder on the goods, and the loss in weight and strength of the goods is greatly reduced.

The Textile Journal of Australia gives a method for bleaching cotton with hydrogen peroxide where the scouring and bleaching operations can be carried successively in the same vessel.[77] The general method consists of a preliminary alkaline

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76 Hubner, J., "Bleaching and Dyeing of Vegetable Fibrous Materials", p.117, Constable & Company, Ltd., London 1927.

77 "Some Notes on the Bleaching of Vegetable Fibers", Textile Colorist", LXII (1941), p.398-400.

boil, with the addition of small amounts of hydrogen peroxide, for five to six hours at 95 degrees centigrade in a liquor containing two grams per liter of sodium silicate, two grams per liter of 100 volumes hydrogen peroxide and two grams per liter of soda ash. Then, the kier is flooded with cold water and the goods washed twice. The main bleaching treatment follows. This consists of treating the goods at 80 degrees to 90 degrees centigrade for six to eight hours in a bath containing six grams per liter of sodium silicate, six grams per liter of 100 volumes hydrogen peroxide and one gram per liter of soda ash. After bleaching, the goods are simply washed well with water and finished.

E. I. DuPont De Nemours and Company, Inc., have patented a method for continuous peroxide bleaching.[78] This process is claimed to be economical, precise, easily controlled, quick and, above all, uniform in its results. The process is described by the inventors as follows. The cloth, after singeing or other preparation, passes into a caustic saturator. After leaving the saturator, the cloth is gathered into a rope and sent to the heater tube where it is uniformly heated from the saturation temperature of about 85 degrees Fahrenheit to the operating temperature of about 210 degrees Fahrenheit. The heated cloth next passes on to the J-box where it is piled and allowed to age for one hour. The cloth is next pulled through a washer and then on to the peroxide saturator.

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78 E. I. DuPont De Nemours & Co., Inc., "Dupont Continuous Peroxide Bleaching Process", Technical Bulletin, 1944.

The cloth remains in the alkaline peroxide saturating solution long enough to become uniformly impregnated and then it is squeezed to remove the excess water and chemicals. The cloth is again passed through a heater tube and into a J-box where it is stored for one hour, then pulled out, washed and piled in the white bin. The total time from gray to bleached goods is two hours and fifteen minutes. The speed of the system is from 100 to 200 yards a minute.

Dr. Rupp[79] recommends the following solutions to be used in the continuous peroxide bleaching method. The caustic saturator should be filled with a solution of caustic soda and some penetrant in such concentration that from two to three percent of caustic is deposited in the goods. The peroxide saturator is filled with a solution containing from two to ten pounds of 100 volumes hydrogen peroxide and ten to fifteen pounds of silicate of soda per hundred gallons of liquor. The solutions used to replenish the used liquors should be about six to eight times as concentrated as the desired saturator strength.

Weiss and Von Reich[80] give the following procedure for bleaching with hydrogen peroxide without a preliminary boil. The goods are treated in a weakly caustic alkaline bath

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79 Rupp, R. E., "Continuous Peroxide Bleaching", American Dyestuff Reporter, XXXI (1942), p. 638-640.

80 Weiss, H., and Von Reich, O.R., "Bleaching Cotton Fabrics and Fibers of Analogous Kind", Journal of the Society of Dyers and Colorists", LV (1939), p.167

containing about two to three percent hydrogen peroxide and about six times the quantity of sodium silicate, at about 90 degrees to 100 degrees centigrade for six hours. After washing, the bleaching process may be carried out a second or third time if desired.

Holt and Kilpatrick[81] have developed a method by which ozone is used. Basically, it consists in giving the goods a normal treatment of hypochlorite after kier boiling. When the goods are impregnated with the bleaching liquor, ozonized air is blown on to them. After this, the goods are finished as in regular hypochlorite bleaching with souring and washing. The inventors claim that by thus doing the goods are protected from the damages of hypochlorites and also that the results are obtained faster.

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81 Holt, T. W. and Kilpatrick, A.S., "Bleaching Fabrics", Journal of the Society of Dyers and Colorists, XLIX, (1933), p.237.

VIII. DETERMINATION OF ACTIVE CHLORINE IN BLEACHING POWDER AND HYPOCHLORITE BLEACHING SOLUTIONS

The price and quality of bleaching powders are based on the percentage of available chlorine they contain. The amount of available chlorine is proportional to the bleaching power of the powder or solution. In other words, the chlorine that is measured is that which will combine with the metallic ion and oxygen to produce the hypochlorite.

A method given by Mahin[82] for determining quantitatively the amount of available chlorine in bleaching powder is as follows. About fifteen grams of the bleaching powder to be tested are accurately weighed and placed in a one-liter volumetric flask. Then, the flask is filled to the mark with cooled distilled water and agitated until the lumps are thoroughly disintegrated, so that soluble matter may be dissolved. Insoluble calcium carbonate remains, but, unless lumpy, this may be disregarded. Fifty-milliliter portions are measured by means of a pipette into Erlenmeyer flasks. To each flask five grams of potassium iodide and twenty-five milliliters of ten percent acetic acid are added, and the whole is titrated with one-tenth normal standard sodium thiosulphate solution, adding starch solution at the last as an indicator. The end point is reached when the solution loses its color. The percentage of

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82 Mahin, E.G., "Quantitative Analysis", p.258-260, McGraw-Hill Book Company, Inc., New York, 1932.

available chlorine is calculated by multiplying the number of milliliters of one-tenth normal thiosulphate used by 0.003546 and by 100, and dividing this product by the number of milliliters in the sample solution titrated.

The American Association of Textile Chemists and Colorists suggests another method of evaluating bleaching powders.[83] Ten grams of the sample are accurately weighed into a mortar and rubbed to a thin cream with water. After allowing the coarse particles to subside, the turbid liquid is poured into a liter flask. The process is repeated with more water until all the powder is transferred to the flask which is then filled to the mark and well shaken. Immediately, fifty milliliters of the turbid solution are pipetted into a beaker and fifty milliliters of one-tenth normal solution of sodium arsenite are added, and the excess is titrated with a one-tenth normal solution of iodine. The percentage of chlorine can be calculated from the number of milliliters of arsenite used minus the number of milliliters of iodine employed to titrate the excess arsenite.

Utermohlen[84] suggests a method of determining the

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83 American Association of Textile Chemists and Colorists, "1942 Year Book", Vol. XIX, p.315 (1943).

84 Utermohlen, H., "Determination of the Hydrolytic Acidity of Bleaching Earths", Journal of the Society of Dyers and Colorists, XLVII (1931), p.336.

bleaching power of bleaching powders by computing the hydrolytic acidity of the samples. This can be estimated by boiling 100 grams of the sample with 200 milliliters of one-tenth normal sodium acetate solution in a Stohmann's 500 milliliter flask for one hour. The product is filtered and 125 milliliters of the solution are titrated with one-tenth normal sodium hydroxide solution using phenolphthalein as indicator. The number of milliliters of sodium hydroxide used represents the hydrolytic acidity and is a measure of the decolorizing power of the bleaching powder tested.

When the samples to be tested are solutions of hypochlorite, the procedure is very much the same. The only difference is that there is no need for dissolving the sample since it is already in solution. The sodium thiosulphate and sodium arsenite methods of titration are optionally used with very satisfactory results.

To the two methods given, a third method may be added as described by Ehrenfriend.[85] A measured volume, in excess, of standard arsenious acid solution is added to the sample of hypochlorite, and the excess is estimated by titration, in acid solution, with standard potassium bromate solution. The indicator used is Methyl Orange, the color of which is

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85 B lakeley, J.D., Preston, J. M. and Scholefield, F., "Determination of Active Chlorine in Hypochlorite Liquors", Journal of the Society of Dyers and Colorists, XLVI (1930), p.230-233.

bleached by the free bromide liberated at the end point.

All these methods are simple, practical means of controlling the bleaching solutions in the bleach house. These methods are given because it has been found that in order to obtain good results in bleaching, the different operations have to be controlled at all times and the materials used must have a certain degree of consistency in their quality. The old Twaddle hydrometer used for such purposes in the bleach house is by far too inaccurate. The density of hypochlorite solutions would be a very good means of finding their bleaching power if they all were made from powders of unchanging chlorine contents. However, the composition and percentage of chlorine of bleaching powders vary to a great entent, making the use of the hydrometer a very crude and inaccurate measurement. The titration methods have found more and more use during the last years in the bleach houses, and they have been greatly simplified by the use of specially graduated burettes and other equipment.

McCrumb, of W. A. Taylor & Company, recommends the use of chlorine slide colorimeters for the determination of the chlorine contents of bleach solutions.[86] This is a simple method and accurate enough for all practical purposes in the bleach house. It has a set of standards, and, by following a simple procedure, it is possible to find in a few minutes

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86 McCrumb, F.R., "New Bleach and Chlorine Control Equipment", Textile Colorist, LIII (1931), pg. 682.

the chlorine content and the strength of the hypochlorite solution tested. The only objection to this method of determining the strength of bleach solutions is that it depends on the human factor for matching the colors.

IX. pH CONTROL IN BLEACHING

The bleaching industry makes use of alkaline and acid solutions in the different stages of the bleaching process. The efficiency of the different operations used depends largely on the right degree of alkalinity or acidity of the solutions employed. With the establishment of the pH scale, some means of determining accurately such conditions was found. By the use of pH measurements it has been possible to eliminate any amount of uncertainty that was at first found in bleacheries, and at the same time any one operation can be duplicated at any time with more certainty. With the pH measurements, it is possible to determine quantitatively the acidity or alkalinity of solutions in contrast with the use of litmus paper, or any such other indicator, which only gives a qualitative idea of the concentration of hydrogen or hydroxyl ions.

The measurement of the pH of a solution is based on the theory of ionization. This theory states that when an acid, base or salt is dissolved in water, it breaks up into ions which are atoms or group of atoms carrying positive or negative electrical charges. Acids will liberate hydrogen ions and bases will liberate hydroxyl ions. Pure water, which may be represented as HOH, ionizes into equal amounts of hydrogen and hydroxyl ions, which is the basis for considering pure water chemically neutral. An acid solution will show

a predominance of hydrogen ions, while an excess of hydroxyl ions will make the solution alkaline.

Kenny and Reed give the following explanation of the pH scale and what it is based on.[87] The mode of expressing hydrogen ion concentration in term of numerical values is very awkward. For instance, the actual hydrogen ion concentration of pure water would be expressed as 0.0000001 or 1×10^{-7} numerically. However, this has been simplified by using the term pH, which means the logarithm of the reciprocal of the hydrogen ion concentration. Thus, the pH of pure water would be 7.0. The range of the present day pH scale is from zero to fourteen. The midpoint is seven, which is the true neutral point. Values higher than seven denote alkalinity, the degree of alkalinity increasing as the numbers increase. Analogously, any values lower than seven denote acidity, the degree of acidity increasing as the number decreases. In order to regulate the pH of solutions, buffers are used. The purpose of the buffers is to maintain a definite pH value in a bath under all conditions of use.

The methods used for measuring the pH of solutions can be classified in two groups: Colorimetric and electrometric. The colorimetric method involves the use of standards of colors obtained with certain indicators at different pH values.

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87 Kenny, W.R. and Reed, A.B., "Simplified pH Control and Its Importance in the Processing of Textiles", Textile Colorist, LIV (1932), p.731-733, 780.

Perley[88] claims that such methods involve a great deal of error due to salts, acids, oxidation and reduction, and other sources. He does not recommend the use of colorimetric measurements of pH values because the conditions under which they are used in the industry are subject to wide variation, thus introducing another important source of error. On the other hand, the electrometric method is based on the measurement of the electromotive force between two half cells, the one a reference and the other the hydrogen ion responsive element. The same author makes clear that this method is not accurate under all conditions, and that here also there are quite a few sources of error, although not quite as great as in the colorimetric measurements. But the variety of electrodes used in connection with such measurements allow for the use of the right electrode for the conditions under consideration. For all practical purposes in the bleaching industry, the glass electrode is recommended. The Beckman pH meter, industrial model, is a very practical instrument for quick determinations of pH values by the electrometric method, which used with the glass electrode is by far the most suitable to use in bleach houses.

The control of the pH values has found its application in all the operations of the bleaching process. Through experimental work and research, certain pH values have been found to give the maximum efficiency and the least detrimental

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88 Perley, G.A., "Modern Views of pH Measurements", American Dyestuff Reporter, XXVI (1937), p.832-836.

action on the cotton. From desizing on to the last wash, pH control plays a very important part.

Kenny and Reed[89] found that in the desizing process, malt diastase acts best at pH 4.0 to 5.0. Pancreatic enzymes are used for the same purpose at pH 7.0, while mould and fungus diastase acts most favorably at pH 5.4. By controlling the pH of the desizing bath and using buffer solutions, the best results at lowest cost can be obtained.

In the kier boiling, the use of pH measurements will help to determine the most efficient length of time required for the exhaustation of the kier charge. It likewise will be an indication of the efficiency of the kier and the rate of exhaustation of the liquor. Rhodes and Bascom[90] found that the detergent action of soap is controlled by the alkalinity of the solution used. The best results are obtained at pH 10.7. On the other hand, they found that in the kier boiling operation the best results can be obtained between pH 11.0 and pH 13.0.

In the souring of the goods, the pH of the solution used will be a good indication of the required time of treatment.

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89 Kenny, W.R. and Reed, A.B., "Simplified pH Control and Its Importance in the Processing of Textiles", Textile Colorist, LIV (1932), p.731-733, 780.

90 Rhodes, F.H. and Bascom, C.H., "Effect of pH on the Detergent Action of Soap", Journal of the Society of Dyers and Colorists, XLVIII (1932), p.47.

Likewise, in the washing operations, by proper pH control, it can be determined whether the goods are free from any acid or base. Thus, the time used in treatments of this kind can be more efficiently set.

The particular bleaching operation where pH evaluations have found their most important use is chemicking. At this stage of bleaching, the acidity or alkalinity of the hypochlorite solutions used will determine their efficiency, stability and detrimental action to the fiber. Many scientists have done a considerable amount of research in this field and some of their findings have been quite helpful to the industry.

Davidson[91] determined the dissociation constant of hypochlorous acid which is 3.7×10^{-8} at 18 degrees to 20 degrees centigrade. He also found that the pH of calcium and sodium hypochlorite solutions in the presence of cotton cloth falls rapidly during the early stages of the bleach, being about pH 8.0 after about two and one-half hours. Addition of partially spent liquor reduces the initial pH of a bleach, owing to the buffer action of the carbonic acid and possibly oxalic acid produced during bleaching, and, although the fall in pH is more gradual, the final value is less than that given by totally fresh solutions.

Ridge and Little[92] set the best range for chemicking as above pH 8.0 and below pH 6.0. In most cases PH 8.0 to pH 11.0 is the range used for best results in chemicking. However, it

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91 Davidson, G.F., "Hypochlorite Solutions", Journal of Society of Dyers and Colorists, XLIX (1933), p.266.

92 Ridge, B.P. and Little, A.H., "Control of PH in Bleaching", American Dyestuff Reporter XXXI (1942), p.515-516, 536.

has been shown that, under specified conditions, solutions approximately neutral can be used and advantage taken of the extreme rapidity of action on the non-cellulose constituents without attacking the cellulose when conditions are controlled. In the neighborhood of pH 7.0 to 8.0 oxidation as well as chlorination can occur, whereas, below pH 6.0 chlorination predominates. By the use of buffers, in spite of a fall in concentration, the pH of the liquor on the goods can remain essentially constant, and reproducible and safe results can be expected. Elod and Vogel[93] found that, when cotton is bleached with sodium hypochlorite, both the efficiency of the bleach and the extent to which the cellulose is degradated, depend upon the pH of the liquor. Thus, when the duration of the bleach is fifteen minutes, maximum degradation of the fiber occurs at pH 7.0 to 8.0, whilst minimum effects are obtained in both respects by bleaching at pH 5.0 and pH 10.0. On the other hand, when the duration of bleaching is extended up to four hours, exactly the opposite effects are observed.

In the antichloring of goods after the chemicking, the pH of the bath largely controls both the speed at which the reaction takes place and its completeness. Therefore, the pH of the bath is a factor to consider in determining the length of time the goods must remain in and the strength or concentration of the antichlor bath.

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93 Elod, E. and Vogel, F., "Bleaching Cotton with Chlorine", Journal of the Society of Dyers and Colorists, LIII (1937), p.115-116.

X. CELLULOSE DEGRADATION IN BLEACHING

The greatest enemy and the greatest problem of the bleaching industry is overbleaching, which results in cellulose degradation. This degradation of cellulose can be due to be the formation of either hydrocellulose, oxycellulose or both. These two substances are usually present in overbelached samples, although in the absence of acid treatments, hydrocellulose is present in a lesser extent. Cellulose degradation takes place not only during the oxidation of the coloring matter but also during the kier boiling of the materials. Unfortunately, the appearance of the goods will not indicate the presence or absence of cellulose degradation. In order to be able to tell whether such degradation has taken place or not in bleaching, it is necessary to test the material either physically or chemically or to examine it under ultra violet light. Furthermore, the chemistry of the products of degradation is so complex and so little is known about their behavior and characteristics that an accurate determination of the presence of such bodies cannot be accomplished quantitatively without the help of elaborate equipment. Therefore, it is common practice to refer to such degradation as "chemical degradation".

Cellulose is almost universally considered to consist of long chains of anhydroglucose units, that is, glucose

units of the pyranose form attached together, with the loss of H and OH at the 1 and 4 positions respectively by primary valences. This structure is represented by the use of perspective formulae. They are also attached together sidewise in the cellulose fiber in a more or less parallel and orderly arrangement by the aid of so-called residual valency forces.[94] Thomas[95] says that when cellulose is attacked by acids there is hydrolysis at the primary glucosidic linkages. The molecule of water that was lost when two of the glucose units were united in the formation of cellulose is replaced and they are broken apart. In this way the chains or chain molecules become broken up into shorter lengths, thus, producing hydrocellulose.

According to Goldthwait[96] the relations in the case of exycellulose are not so well understood, but the fall in tensile strength and increase in fluidity, as measured by cuprammonium test, indicates clearly that the chain molecules are broken up also.

According to Ott[97] the glucosidic linkages may not be attacked at the beginning of the reaction. Rather, the

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94 Wertheim, E., "Textbook of Organic Chemistry", p.365, The Blakiston Company, Philadelphia, (1939).

95 Thomas, H. A., "Oxycellulose and Hydrocellulose", American Dyestuff Reporter, XXII (1933), p.355-356, 371-377.

96 Goldthwait, C., "Hydrocellulose and Oxycellulose", American Dyestuff Reporter, XXVII (1938), p.692-694.

97 Ott, Emil, "Cellulose and Cellulose Derivatives", p.184, Interscience Publishers, Inc., New York, N. Y., (1943).

primary alcohol group in the glucose unit is first oxidized to an aldehyde, and the latter in turn oxidized to a carboxyl or acid group. It is not yet entirely clear whether these reactions are accompanied by a breaking of the primary valence bonds between chains or the bonds are merely weakened. The aldehyde and acid products of oxidation may exist side by side and in a variety of proportions, depending upon the origin of the reaction product.[98] Davidson found that the pH of the oxidizing media will affect the nature of the products of oxidation ranging from the reducing to the acidic type as the pH increases.

Whatever the structure of these products may be, the fact remains that they are products of cellulose degradation and that they are a breaking up of the regular cellulose molecule into shorter units. Hydrocellulose will result from the hydrolytic action of acids, while oxycellulose is produced by acid or alkaline oxidation of the cellulose. However when acid oxidation occurs, oxycellulose and hydrocellulose are formed. Both are characterized by a considerable loss in strength of material and by a tendency of the bleached product to stain on storage.

Cellulose degradation will be present in the kier boil if the goods are treated at high temperatures with the alkaline solution before all the air has been expelled from the kier. Furthermore, the cellulose degradation obtained this way is not evenly distributed on the goods but will be present at random, forming spots wherever the hot lye came in contact

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98 Davidson, G.F., "The Modification of Cellulose by Oxidation", Journal of the Society of Dyers and Colorists, LVI (1940), p58-67.

with the goods in the presence of air. Also, exposure of the goods saturated with hot lye to the air will cause great amounts of cellulose degradation.

In the chemicking operation cellulose degradation may occur by the use of too concentrated bleach liquors, by the actual bleaching lasting too long, or by too high temperature being maintained during the operation. Any grains of undissolved bleaching powder which may be present in the bleach liquor are capable of deteriorating the cellulose by developing a more intensified bleaching action in their vicinity. Ommission of the wash-off between bleaching and souring is also a potential cause of trouble. The presence of small particles of rust or dust which act as oxygen carriers will cause small localized areas of degradation. This may also be due to unremoved proteins which react with the hypochlorite to give chloramines. Unremoved mineral acids from the fabric, which, although used in low strengths, are concentrated in drying, cause cellulose degradation in the fiber. The control of the pH of the bleaching solution will prevent overbleaching to a great extent.

A method of determining the presence of the excessive cellulose degradation is by testing the tensile strength of the material bleached. Undue weakening of the goods will indicate, beyond any doubt, the presence of excessive degradation. However, this is the only physical test for any detriment of the goods in bleaching, and if the amount of degradation products present is very small, this test will not be of any use. On the other hand, many tests have been developed to identify these

products of degradation by chemical means. Most of the tests used are based on the reducing properties of the degradated cellulose. They are more sensitive tests and give better and more certain results.

Sommer and Markert[99] recommend the silver test as the most useful for a qualitative test of oxycellulose. A one percent solution of silver nitrate is taken and quantity sufficient of ammonia added to cause the precipitate to redissolve. The sample is boiled in this solution and a brown stain indicates oxycellulose. Hydrocellulose gives a much weaker reaction. Undamaged cotton will not be stained.

Holmes[100] recommends the use of Nessler's Reagent. This reagent is a solution of mercuric iodide in caustic soda. It is said to be possible to tell the extent of any damage in bleaching by merely sprinkling it on the sample and noting if any stain is produced. The intensity of the stain gives an indication of the extent of the damage.

Fennell[101] emphasizes the usefulness of the Cuprammonium Fluidity test for determining the degree of cellulose degradation present. This method is quite elaborate and is not

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99 Sommer, H. and Markert, H., "Detection of Oxy-and Hydrocelluloses", Journal of the Society of Dyers and Colorists, XLVII (1931), p.304.

100 Holmes, J. F., "Oxycellulose", Textile Colorist, LVI (1934), p.307-308

101 Fennell, F.L., "The Significance and Utility of Cuprammonium Fluidity in T extile Bleaching", American Dyestuff Reporter, XXX (1941), p.481-486.

practical for use in the bleach house. It requires quite a special technique, and it is more a laboratory method. This test is based on the principle that the degradation of cellulose is a breaking up of the cellulose molecule into shorter chains; therefore, with greater degradation, the fluidity of the cuprammonium solution is increased. The measurements found with this test are a true index of the cellulose degradation present.

Ermen[102] has developed a Ferricyanide Reagent for the detection of oxycellulose. The reagent consists of a fourteen-percent solution of ammonium iron alum and a seven-percent solution of potassium ferricyanide. Two milliliters of the former and one milliliter of the latter are mixed with eight milliliters of glacial acetic acid and water to make 100 milliliters. The samples to be tested are treated for five minutes with this solution over a water bath. A greenish blue color gradually develops which is proportional to the degree of degradation of the cotton. The color thus obtained is not affected by washing with water.

Haller[103] uses the following test for determining the degradation of cellulose. The samples are steeped for one to two hours in a cold solution of one percent stannous chloride. Then they are treated with a very dilute solution of gold chloride. A purple color will develop very rapidly in the presence of oxycellulose. The reaction is due to the increased affinity of

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102 Ermen, WFA, "An Improved Ferricyanide Reagent for the Detection of Oxycellulose", Journal of the Society of Dyers and Colorists, XLVII, (1931), p.211.

103 Haller, R., "Differentiation Between Hydrocellulose and Oxycellulose", Journal of the Society of Dyers and Colorists, XLVII (1931), p.211

oxycellulose for metal salts as compared to undamaged cotton.

Other simple tests based on the decreased affinity of chemically degraded cellulose for certain direct dyes, or the increased affinity of these products for basic dyes as compared to undamaged cellulose have been developed. However, they leave a great amount of doubt when the quantities of degradated cellulose present are very small. Furthermore, a test for oxycellulose has been designed making use of its reducing properties. A vat yellow dye is used in caustic soda solution where the samples to be tested are treated. The oxycellulose will reduce the vat color to its leuco form and absorb it which, upon oxidation and washing will show as a yellow stain. The undamaged cotton will not be affected.

XI. REVIEW OF THE LITERATURE

From the library research conducted, it has not been possible to find any one work that will cover the subject of the present thesis. Considerable amount of work has been recorded on parts of this study. However, no one author has applied the actual industrial processes to the laboratory experimental work. In other cases no standard tests were used for measuring the results obtained. Finally, the present plan of attack on the subject apparently has not been used previously on cotton fabrics, and this finding gives some certainty as to the need for the present study.

J. G. Williams[104] conducted a program of experimental work on the tensile strength of wet and dry yarns after deterioration by the hypochlorite bleach. Unfortunately, the author did not use any standard tests in such determinations, and the main object of the work was to draw a comparison of the deterioration of viscose and cotton. However, a set relation was found between the loss in tensile strength of cotton yarns and the amount of overbleaching. No attempt was made to place the origin of overbleaching, since the treatment used was a simple chemicking operation so controlled as to purposely damage the fiber to varying degrees.

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104 Williams, J. G., "Tensile Strength of Wet and Air-dry Yarns of Cotton and Viscose Silk After Deterioration by the Action of Ultraviolet Light or of Hypochlorite Bleach", Journal of the Society of Dyers and Colorists, XLVIII (1932), p.167-169.

E. Butterworth[105] performed an extensive study of cellulose bleaching, but the fibers used for such work were mainly bast fibers. Nevertheless, some of his findings are a good indication of the results to be expected in the bleaching of cotton. The author found that in the bleaching of linen the solubility number of the fiber increases with an increase in concentration, while an increase of ratio of liquor shows no greater damage. Likewise, determination of the effects of kier boil and temperature of chemicking were conducted. In both cases an increase in time and concentration produced a reduction in tensile strength. However, it was found that the degree of whiteness of the goods does not increase in proportion to the amount of overbleaching.

E. Kornreich[106] completing the work of Butterworth, claims that in the bleaching of cellulose with hypochlorites, the presence of the proteins of the fiber accounts for a percentage of the loss in strength. Kornreich sets a definite relationship between the color of the bleach, the loss in tensile strength and the protein contents of the fiber. The experimental work does not use any standard tests, but the bleaching operations were conducted under such conditions so as not to damage the cellulose by oxidation. All the damage produced in the

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105 Butterworth, E., "The Bleaching of Cellulose with Special Reference to Bast Fibers", Journal of the Society of Dyers and Colorists, LV (1939), p.589-596.

106 Kornreich, E., "Bleaching Cellulose", Journal of the Society of Dyers and Colorists", LVI (1940), p.352-355.

fiber is attributed to the chloramines formed by the proteins.

Johnson, Anderson, Parker and MacMahon[107] conducted an investigation on the interrelation of whiteness and tensile strength when bleaching agents were used in laundering. From the data compiled, it is concluded that the degree of whiteness obtained is inversely proportional to the tensile strength after the chemicking operation at a certain point. However, the tests were carried on goods which had already been bleached. This fact may account for the greater loss found in tensile strength.

G. B. Jambuserwala[108] conducted a very intensive and interesting study of the degrees of whiteness obtainable by bleaching in relation to different varieties of cotton. The purity of the bleached samples was estimated by the residual ash and fatty matter contents. The whiteness was measured by the intensity of the daylight reflected by the surface of the samples by the use of a photo-electric cell equipped with an amplifier and a galvanometer. Finally, the two results obtained were correlated by visual estimations of differences in whiteness. The bleachings were carried out by using varying methods of kier boiling and time of chemicking. The concentrations used in the bleaching liquors were not studied. Likewise, the relations of whiteness and tensile strength were not taken into consideration. Attempts were made to insure the least amount of cellulose

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107 Johnson, G. H. Anderson, A. I., Parker, H. O. and MacMahon, J. D., "The Influence of Bleaching in the Whiteness and Tensile Strength of Cotton Fabrics", American Dyestuff Reporter, XXIII (1934), p.519-520.

108 Jambuserwala, G.B., "Degree of Whiteness Obtainable by Bleaching", American Dyestuff Reporter, XXVI, (1937), p.799-802, 820.

degradation in the samples obtained.

After having carefully scrutinized all available records on the subject, the following conclusion has been reached. No work has been done, to the best of our knowledge, that will cover a complete study of the conditions used in chemicking as to concentration of hypochlorite solution, length of time of treatment and temperature of treatment. Likewise, no record has been found of any attempt to correlate the bleached results obtained as to whiteness and tensile strength with the above conditions. Upon completion of this work, it is hoped to draw definite conclusions as to such relations of whiteness and tensile strength and the factors contributing to the obtainment of the best bleached results.

SECTION II

EXPERIMENTAL

I. GENERAL EXPERIMENTAL PROCEDURE

The main purpose in setting up the following experimental conditions has been to reproduce, as closely as practical, those which would be found in actual practice in the bleach house. Therefore, it will be observed that some operations that are normally conducted in the laboratory have been omitted because they would be uneconomical or impossible to reproduce in plant operation.

Since the only variables to be considered in the present work are in the actual chemicking process, all of the fabric used in the various tests was treated in the desizing, kier boiling and antichloring operations by the same method and under the same conditions. These methods were selected because they have been found in previous work to be satisfactory and commonly used in industry.

The gray cotton fabric was divided into three lots. Two lots were of forty-one yards each and the third lot was of forty yards. The material was allowed to condition at 70 degrees Fahrenheit and 65 percent relative humidity for one week. After this time, each lot was weighed and marked with standard eighteen-inch marks in both warp and filling directions for the determination of shrinkage.

The next step was to desize the material. The fabric was treated with two percent Exsize and one-half percent Santomerse D, based on the weight of the fabric. The Exsize

is a starch splitting and the Santomerse D a penetrant. The fabric was steeped for two hours at 145 degrees Fahrenheit in a fifteen to one bath. The technique used in this operation was to heat the desired volume of water to the temperature required. The Santomerse D was added by previously dissolving in hot water, and finally the Exsize was poured in the bath. The solution was not allowed to exceed 145 degrees Fahrenheit. This eliminated the danger of killing the enzyme and reducing the efficiency of the bath. The fabric was soaked thoroughly two hours and allowed to stand in the bath until the full two hours of treatment were completed. During the desizing treatment, samples of the bath liquor were withdrawn to measure the pH of the solution before the fabric was entered and every fifteen minutes thereafter.

After desizing, the fabric was given a fifteen-minute wash at 145 degrees Fahrenheit and a thirty-minute two-change cold wash. A hot wash is not practical from the standpoint of cost.

After the cold wash, the fabric was extracted and then evenly and carefully packed in the kier. The kier had previously been whitewashed with lime and lined with cotton fabric. These precautions were taken in order to prevent any rust from coming in contact with the material during the kier boiling process. Once the goods were well and evenly packed, the kier was filled with water and allowed to stand over-night in order to expel all the air that may have been present.

When all the air was removed, the kier charge was

added. The charge consisted of three percent caustic soda, three-fourths percent neutral soap, and one-half percent Santomerse D on the weight of the fabric. The caustic soda and the soap were used as the detergent agents and the Santomerse D was used as a penetrant to insure thorough circulation of the kier liquor. With the lid open, the kier was circulated for one hour cold to insure even distribution of the chemicals throughout the kier. At the end of this period, the lid was closed and a sample of liquor was taken to measure the original pH. Heating was started with the safety valve open. When steam began to be generated, the safety valve was closed and the pressure allowed to build up to fifteen pounds at which point it was kept for eight hours. When the full fifteen pounds of pressure were obtained, a second sample of the kier liquor was removed to measure the pH, and successive samples were tested every thirty minutes. At fifteen pounds of pressure, the boiling point of the kier liquor was 255 degrees Fahrenheit.

After eight hours of kier boiling, the fabric was given a fifteen-minute wash at 160 degrees Fahrenheit and a fifteen-minute cold wash, both in the kier. When the kier was cooled, the lid was opened and the fabric removed to an open vessel where it was given a fifteen-minute wash at 160 degrees Fahrenheit and a thirty-minute two-change cold wash. Finally, the fabric was extracted and allowed to dry in the drying chamber. Here again it can be noticed that the hot washes were omitted because they are not practical in industry.

The purpose of the kier boil is to remove as much of the natural impurities in the cotton as possible. The detergent agents saponify the fatty matter and waxes, at the same time that they attack the pectine matter and other impurities.

When the fabric was dry, it was carried into the conditioning room and allowed to condition for forty-eight hours at 70 degrees Fahrenheit and 65 percent relative humidity. The same procedure was followed with all three lots. After conditioning, the weight of each lot was recorded and the shrinkage measured. The lots were cut into thirty-three inch samples to be used in the chemicking process. The conditioned weight of these samples was recorded, and each sample was marked in order to determine the shrinkage in the next operation. Samples of gray fabric and of each run in the desizing, and kier boiling operations were saved to be used in the testing of the results obtained.

The chemicking process, the main interest of this work, was designed in such a manner that the time of treatment, the concentration of the sodium hypochlorite solution, and the temperature of treatment could be varied over a definite range. The time of treatment was fifteen, thirty, forty-five, sixty, seventy-five and ninety minutes. The concentrations of hypochlorite solution used were: one, two, three, four, five and six grams of available chlorine per liter. The temperatures used were: room temperature (76 degrees Fahrenheit), twenty degrees Fahrenheit above room temperature (96 degrees Fahrenheit) and forty degrees Fahrenheit above room temperature (116 degrees

Fahrenheit). The periods of time selected were such that incomplete bleaching, normal bleaching and overbleaching could be expected. Periods of over ninety minutes, although used in industry, would not be practical in all cases. Periods of fifteen minutes, although very short, were selected because they were expected to give some definite information as to the effects of the bleaching process over short periods of time. The concentrations of bleaching solution selected were those that from previous work were known to produce incomplete bleaching and overbleaching on the fabrics. The temperatures of treatment used were those that were expected to give good results, and not over 120 degrees Fahrenheit at which temperature it is known that the hypochlorites will decompose into chlorates.

In all, one hundred and eight different sets of conditions were used, and they are tabulated in Table V.

The experiments, although independent of each other, were carried out in series of six to a bath. A ratio of liquor to fabric of fifteen to one was used, and the bleaching solution was titrated by the sodium thiosulphate method at the beginning of each run and every fifteen minutes to determine the rate of drop in available chlorine per liter. Measurements of the pH of the solutions were carried out at the same time intervals. The samples combined in each set were those which required the same concentration of hypochlorite solution and the same temperature, and the variable used was the time factor. Every fifteen minutes a sample of the material was withdrawn, and, at the same time, the corresponding volume of liquor was

removed from the bath in order to maintain the ratio of liquor to material constant at all times.

When the bleaching baths to be used required room temperature (76 degrees Fahrenheit), the baths were prepared by diluting the titrated stock solution of sodium hypochlorite with enough cold water until the required strength and volume were obtained. In the case of above room temperature (76 degrees Fahrenheit), the solutions were prepared by diluting the stock solution with water of temperature slightly above that which was desired. When the right strength, volume and temperature were obtained, the vessels were heated to maintain the temperature constant throughout the bleaching operation.

The purpose of the chemicking treatment is to bleach the coloring matter left in the goods after the kier boiling process. The removal of the coloring matter is accomplished in the case of the hypochlorite bleach by the oxidation of the coloring substances to soluble leuco compounds which are later removed by washing. After the samples had been chemicked, they were thoroughly washed with cold water and then submitted to an anti-chlor treatment with one-half percent solution of sodium thiosulphate for thirty minutes. Each sample was treated in an independent fifteen to one bath, and the pH of the solution was measured at the beginning, after fifteen minutes and after thirty minutes of treatment. After the antichlor treatment the goods were again thoroughly washed in cold water and then allowed to dry in the drying chamber.

The antichlor treatment was given in order to eliminate any probabilities of damage of the material by the action of the chlorine that may not have been removed in the washing operation after bleaching. However, the antichlor treatment produces a certain amount of hydrochloric acid that has to be removed, but which is eliminated by simple washing with cold water.

After the samples were dry, they were removed to the conditioning laboratory where they were allowed to condition for seventy-two hours at 70 degrees Fahrenheit and 65 percent relative humidity. Under normal mill practice, a period of twelve hours would be considered sufficient for conditioning small samples. However, it was thought advantageous to use seventy-two hours in this case because it eliminated any error that may have been due to improper conditioning.

II. GENERAL TESTING PROCEDURE

In order to evaluate the results obtained with the different sets of bleaching conditions used as compared to the untreated material, it was necessary to conduct a systematic testing procedure. The tests performed were: loss in weight of the fabric, shrinkage of the fabric, change in texture of the fabric, change in light reflection or whiteness index of the fabric, change in tensile strength of the fabric and absorbency of the fabric.

In all possible instances, the standard methods of the American Society for Testing Material were used. However, when no such standards were available, tests were used which could be performed with the equipment available. As a whole, the tests selected were those which are commonly used in industry, and all specimens were conditioned for at least forty-eight hours.

The tests for loss in weight of the fabric were carried out by using the conditioned weight of one-yard samples. The samples were allowed to condition under standard conditions of 70 degrees Fahrenheit and 65 percent relative humidity, for at least forty-eight hours. The bone-dry weights were not used because the size of the samples to be handled made such procedure very inaccurate. This test was applied in all cases when the goods were submitted to a chemical treatment which would cause a loss in weight. The weight of the original

gray fabric was determined using three samples for an average. The weight of the desized product was also found using three weighings to give the average. The weight of the scoured fabric was also found by suing three different samples. Finally, the weight of the bleached products was found by using only one sample because in each bleaching operation the material used was of less than a yard. However, each sample was weighed before and after chemicking, and fairly accurate results were thus obtained.

It was important to find the loss in weight during the different operations in order to follow the manner in which the impurities were removed from the fabric. It also was necessary to know in which manner the different chemicking conditions affected the weight of the fabric. Furthermore, it was necessary to know the loss in weight at the different stages of bleaching in order to correct the comparison samples to the same conditions. In all cases the loss in weight was calculated as a percentage of the weight of the samples previous to the operation under consideration.

In determining the shrinkage of the fabric, the standard procedure of the American Society for Testing Material[109] was used. This standard calls for the marking of the fabric when it is laid flat on a smooth surface and all the wrinkles have been removed. Three distances of eighteen inches were

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[109] "A.S.T.M. Standards on Textile Materials" D437-36, p.135, American Society for Testing Materials, Philadelphia, Pa., 1944.

marked with indelible ink in both warp and filling directions. The distances taken were parallel to the warp or filling threads, at least six inches apart, and at least six inches from the edges of the samples. This operation was carried out before the goods were submitted to the next treatment.

After each operation, the samples were dried and then laid out on a smooth surface and pressed with a hand iron by simply applying the weight of the iron on the fabric. The samples were allowed to cool to standard conditions and then measured with a ruler that gave the readings directly as percent shrinkage. The average of the readings in each direction was used as the shrinkage of the fabric.

This test was carried out in order to determine the rate of shrinkage of the goods under the different operations. The shrinkage measured was total shrinkage, that is, that the fabric was under no stress whatsoever all throughout the different treatments. This test was also necessary in order to correct the comparison samples to similar conditions.

The change in texture of the fabric was determined in accordance with the standards of the American Society for Testing Materials.[110] The test was conducted by counting the actual number of ends or picks in one inch of material at five different places on the fabric and the average taken. No count was made at less than six inches from the selvages and the edges of the samples. Likewise, in no count were the same sets of threads used, so

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110 "A.S.T.M. Standards on Textile Materials" D 39-39, p.75, American Society for Testing Materials, Philadelphia, Pa., 1944.

that a good cross section of the material would be insured. The results were given as number of ends or picks per inch.

The change in texture in the fabric was essential to the proper correction of the comparison samples to equal conditions. It also could be used as a check of the results obtained in the test for shrinkage. That is, the number of ends or picks obtained by count should be equal to the number of ends or picks of the original sample plus the percentage of shrinkage of the fabric.

The change in light reflection or whiteness index of the fabric was measured, because it is the only means available of measuring instrumentally the degree of whiteness obtained on the fabric. By means of a special unit, the electromotive force of the light reflected through a photoelectric cell is recorded and compared to a standard of one hundred percent light reflection. Two measurements were made using a red filter. One reading was with one hundred percent light reflection, and the other reading was with suppressed zero. The one hundred percent light reflection reading gave the amount of white shine of the fabric. The suppressed zero reading gave the degree of white opacity of the fabric. Readings were carried out on the gray, scoured and bleached fabric.

This test has not been standardized yet, but it has been found in the present study that the above procedure gave satisfactory results. However, the measurements obtained gave very close readings and in some cases it was impossible to distinguish between two samples. Nevertheless, it is safe to consider such measurements as satisfactory. It also was found

that the instrument gave the same readings all throughout the samples, and, therefore, it was considered unnecessary to use average readings.

The tensile strength of the fabric was measured by the standard method given by the American Society for Testing Materials as the Raveled-Strip test.[111] This test calls for samples of six and a half inches in length and one and a half inches in width. These specimens are to be cut from the fabric material at least six inches from the edges of the sample to be tested. The specimens are raveled down from one and a half inches to one inch in width, taking approximately equal number of threads from both sides. The average of five warp and five filling specimens is required as a minimum. The samples are broken on a tensile testing machine with the jaws set at three inches. The jaws used must have faces measuring one inch by two inches, the longer direction being perpendicular to the direction of application of the load. Samples breaking at the jaws, at the edges of the jaws, slipping, or of evident faulty operation, should be discarded and another specimen used instead. Tests were conducted on the gray, desized, scoured and bleached fabric.

This test was selected because it gives more refined results and eliminates any fabric assistance that may be found in the grab method. Since the tensile strength of the material is one of the main points to be measured in the present work,

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[111] "A.S.T.M. Standards on Textile Materials" D 39-39, p.75 American Society for Testing Materials", Philadelphia, Pa., 1944.

it was necessary to use the best method suitable to the material. By finding the change in tensile strength caused by different bleaching conditions, an indication of the amount of deterioration of the goods could be obtained.

Finally, the absorbency of the material was tested in order to determine whether the goods had been properly freed from impurities, especially waxes. The absorbency of the material is also a good indication of the quality of the bleach obtained, the product being more absorbent with a more thorough bleach.

The method used in carrying out this test is not a standard method, but since there is not such a standard, the procedure followed is simple and easy to perform. This test calls for samples cut from the material in disk shape over the cross section of the fabric and at least six inches from the selvages. The disks used were two inches in diameter and had been conditioned for over forty-eight hours. A vessel is filled with water as close to the top as possible and the liquid is allowed to condition to seventy degrees Fahrenheit. The samples were handled with tweezers in order to avoid any impurities from depositing on them. Five specimens per sample were used, and each one is placed on the surface of the water until it will start sinking by its own weight. The time it takes for the sample to start sinking once it is placed on the liquid is an indication of the absorbency of the fabric. The average of all five samples will give the degree of absorbency of the material tested. This test was performed on the gray fabric, desized fabric, scoured fabric, and bleached fabric.

III. MATERIALS USED

The gray cotton fabric material used in the performance of the present study was a three-one twill made with carded yarns. The texture was 98 ends per inch by 55 picks per inch, 1.98 yards per pound and 35.5 inches wide. It had an average tensile strength of 129.8 pounds warpwise and 89.8 pounds fillingwise. There was no particular reason for selecting this material, except that it is used in the manufacture of Navy uniforms and it is bleached in great quantities.

The water used was city supply water softened for textile purposes at the A. French Textile School.

The desizing agent Exsize, used in the performance of this work, is a product of the Premier-Pabst Sales Co.

Santomerse D, used as a penetrant in the desizing and kier boiling processes, is a product of the Monsanto Chemical Company.

The caustic soda, used in the kier boils, is a product of the Mathieson Alkali Works, Inc. and was 98.00 percent pure. Likewise the neutral soap used was 99.00 percent pure soap.

The sodium hypochlorite solution used in the chemicking operations was prepared from H.T.H., a product of the Mathieson Alkali Works, Inc. This substance, upon testing by the sodium thiosulphate titration method, gave seventy-one percent of available chlorine. The sodium hypochlorite solution was prepared by dissolving five pounds of H.T.H. in twenty gallons

of lukewarm water. The mixture was stirred for five minutes and then eight pounds of soda ash, manufactured by the same company, were added in small portions and the whole stirred for ten more minutes. The solution was allowed to settle for four hours, and then titrated to determine the amount of available chlorine. This solution, used as a stock solution, titrated at twenty grams of available chlorine per liter or a two percent solution. The pH of the solution was 11.7.

In the antichlor operation sodium thiosulphate technically pure was used.

In all the titrations, sodium thiosulphate was used because it was considered the most suitable method. Along with the sodium thiosulphate in a solution of one-tenth normal, a thirty percent solution of potassium iodide and a fifty percent solution of acetic acid were used.

IV. EQUIPMENT USED

The desizing and washing operations were carried out in common open vessels. These vessels, which had a capacity of forty gallons, were lined with monel metal and heated by means of live steam. However, in order to give the fabric a more thorough working, a wringer was connected to the vessels through which the material was circulated.

In the kier boils an Allen Worcester Circulating kier was used. This kier is equipped with a centrifugal pump to insure better circulation of the liquor at a pump pressure of ten pounds. The pressure capacity of the kier is thirty-five pounds, but in the present runs the safety valve was set to fifteen pounds. The kier is also equiped with a super-heater unit which heats the solution in the kier as it is circulated by the pump, thus insuring a constant volume because no steam is introduced into the machine. The ratio of liquor to material is ten to one, and the kier has a capacity of twenty-five pounds.

The pH measurements were made with the Beckman pH Meter Industrial model. When the solutions to be measured had low sodium ion concentrations a No. 4990 glass electrode was used. However, when the sodium ion concentration of the solution was high a No. 4990-E glass electrode was preferred. The buffer solutions used for calibrating the pH meter were

of pH 7.0 and 4.0. Readings that had to be taken above 25 degrees centigrade were recorded with the instrument calibrated to that temperature and then the readings corrected to twenty-five degrees centigrade.

All the titrations were carried out using graduated burettes with readings to one-tenth of a milliliter. The water used in this operation was distilled water, and all the solutions were standardized before using.

In the chemicking process the stock solution was prepared in earthware vessels. The bleaching solutions used were placed in double enamel boilers of six gallon capacity.

The scales used in the weighing of the samples were standard double beam balances accurate to one-tenth of a gram. The capacity of the scales was 500 grams.

In the marking of the specimens for the measurements of the percentage of shrinkage, a standard eighteen-inch device was used. The percentage shrinkage was read directly with a specially graduated ruler.

The texture of the fabric was inspected with a standard one-inch pick glass.

The light reflection or whiteness index of the goods was measured with the Photovolt Photoelectric Reflection Meter, Model 610. This instrument is equipped with a photoelectric cell and search light placed in an independent search unit. In all readings the red filter was used, and the standard used to calibrate the instrument was magnesium carbonate.

The machine used in measuring the tensile strength of the fabric was a Scott Vertical Combination Fabric and Yarn Pendulum type tensile testing machine. This piece of equipment is in conformity with the requirements of the American Society for Testing Materials. Before the machine was used, the jaws were carefully checked to determine whether they matched or not and then set exactly three inches apart. Likewise, the machine was calibrated against known weights in accordance with the method given by the American Society for Testing Materials.[112]

As a whole, it can be stated that all the equipment used in all phases of this experimental work is standard equipment used in industry. All machines and instruments were carefully checked and calibrated before any tests were performed; thus eliminating any possible error that may have been due to faulty equipment.

The conditions of standard humidity and temperature in the testing labroatory were checked every two hours. A record of the performance of the equipment was kept all throughout the time such laboratory was used.

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112 "A.S.T.M. Standards on Textile Materials" -E 4-36, p.355, American Society for Testing Materials, Philadelphia, Pa., 1944.

V. EXPERIMENTS

In order to avoid unnecessary repetition, the three different runs in desizing and kier boiling have been grouped under the general heading of the operation. Likewise, the experiments in chemicking have been grouped in sets of six. These sets are groups of experiments which required the same concentration of hypochlorite bleaching solution and the same temperature of treatment. Thus, the only variable in each set is the time factor. The results of each experiment, along with the results of the tests conducted are listed individually. The antichlor treatment is given as a single process for all samples.

DESIZING. This operation was performed in three runs, each of which used two percent Exsize and one-half percent Santomerse D on the weight of the fabric. A 15 to 1 bath was used at 145 degrees Fahrenheit for two hours. A fifteen-minute wash at 145 degrees Fahrenheit and a thirty-minute two-change cold wash were given.

Run No. 1. The pH change in this operation was an increase of 0.1 from the original pH of 6.80 to 6.90.

The weight per yard dropped from 225.1 to 212.9 grams, representing 7.7 percent of size removed.

The texture of the fabric changed from 98 to 102 ends per inch, and from 55 to 61 picks per inch.

The tensile strength of the fabric changed from 129.8 to 123 pounds warpwise and from 89.8 to 101 pounds

fillingwise.

The absorbency of the fabric was improved from over 1800 seconds to 340 seconds.

Run No. 2. The pH change in this operation was an increase of 0.1 from the original of 6.8 to 6.9.

The weight per yard dropped from 235.1 to 212.9 grams per yard, representing 7.7 percent of size removed.

The texture of the fabric changed from 98 to 102 ends per inch and from 55 to 60 picks per inch.

The tensile strength of the fabric changed from 129.8 to 123 pounds warpwise and from 89.8 to 105 pounds fillingwise .

The absorbency of the fabric was improved from over 1800 seconds to 360 seconds.

Run No. 3. The pH change in this operation was an increase of 0.1 from the original pH of 6.8 to 6.9.

The weight per yard dropped from 223.7 to 210.1 grams, representing 8.0 percent of size removed.

The texture of the fabric changed from 98 to 103 ends per inch and from 55 to 62 picks per inch.

The tensile strength of the fabric changed from 129.8 to 121 pounds warpwise and from 89.8 to 101 pounds fillingwise.

The absorbency of the fabric was improved from over 1800 seconds to 350 seconds.

KIER BOILING. This operation was performed in three runs also, each of which used three percent caustic soda, three-fourths percent neutral soap and one-half percent Santomerse D on the weight of the goods. The boils were conducted for eight

hours at fifteen pounds pressure and with a boiling point of 255 degrees Fahrenheit. The fabric was given a fifteen-minute wash at 160 degrees Fahrenheit and a fifteen-minute wash cold, both in the kier. Further washing was given in an open vessel for fifteen minutes at 160 degrees Fahrenheit and for thirty minutes with two changes cold.

Run No. 1. The pH change in this operation was a decrease of 0.4 from the original pH of 11.3 to 10.9.

The weight per yard dropped from 212.9 to 197.5 grams per yard representing a net removal of 4.6 percent impurities.

The total warp shrinkage was 9.8 percent and the total filling shrinkage was 5.6 percent from the gray fabric.

The texture of the fabric changed from 102 to 103 ends per inch and from 61 to 62 picks per inch.

The light reflection as measured with the red filter and suppressed zero or white opacity improved from 55 to 63 percent. The measurement with 100 percent light reflection or white shine improved from 78 to 81 percent.

The tensile strength of the fabric changed from 123 to 126 pounds warpwise and from 101 to 108 pounds fillingwise.

The absorbency of the fabric was improved from 340 to 4.9 seconds.

Run No. 2. The pH change in this operation was a decrease of 0.4 from the original pH of 11.4 to 11.0.

The weight per yard dropped from 213.3 to 197.9 grams per yard representing a net removal of 7.0 percent impurities.

The total warp shrinkage was 9.7 percent and the total

filling shrinkage was 5.5 percent from the gray fabric.

The texture of the fabric changed from 102 to 103 ends per inch and from 60 to 61 picks per inch.

The light reflection as measured with the red filter and suppressed zero or white opacity improved from 55 to 63 percent. The measurement with 100 percent light reflection or white shine improved from 78 to 81 percent.

The tensile strength of the fabric changed from 123 to 126 pounds warpwise and from 105 to 112 pounds fillingwise.

The absorbency of the fabric was improved from 360 seconds to 4.3 seconds.

Run No. 3. The pH change in this operation was a decrease of 0.4 from the original pH of 11.4 to 11.0.

The weight per yard dropped from 210.1 to 194.9 grams per yard representing a net removal of 4.8 percent impurities.

The total warp shrinkage was 9.9 percent, and the total filling shrinkage was 5.4 percent from the gray fabric.

The texture of the fabric changed from 103 to 104 ends per inch and from 62 to 63 picks per inch.

The light reflection as measured with the red filter and suppressed zero or white opacity improved from 55 to 63 percent. The measurement with 100 percent light reflection or white shine improved from 78 to 81 percent.

The tensile strength of the fabric changed from 121 to 124 pounds warpwise and from 101 to 108 pounds fillingwise.

The absorbency of the fabric was improved from 3.40 to 4.6 seconds.

CHEMICKING. The concentrations used in the following experiments were: one, two, three, four, five and six grams per liter. The lengths of time of treatment used were: fifteen, thirty, forty-five, sixty, seventy-five and ninety minutes. The temperatures of treatment were: seventy-six, ninety-six, and one hundred and sixteen degrees Fahrenheit.

All breaking strengths of the results obtained are compared to the desized breaking strength found. This break has been corrected to similar conditions of shrinkage and loss in weight for both warp and filling as found in this work.

EXPERIMENTAL SET I. (Experiments 1 to 6)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of one gram of chlorine available per liter. The temperature of treatment was seventy-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	1	2	3	4	5	6
Total loss in pH	0.20	0.40	0.50	0.50	0.50	0.50
Total grams of chlorine used up	0.3195	0.4260	0.5325	0.6390	0.7455	0.8520
Net percent lost in chemicking	0.50	0.55	0.60	0.55	0.60	0.65
Net percent warp shrinkage	3.90	3.80	4.00	4.00	3.90	3.80
Net percent filling shrinkage	2.40	2.40	2.30	2.40	2.20	2.40
Average ends per inch ...	107.20	107.00	107.20	107.40	107.20	107.20
Average picks per inch ..	63.40	63.40	63.40	63.40	63.20	63.40
Percent white opacity ...	73.00	74.00	75.00	76.00	76.00	76.00
Percent white shine	86.00	87.00	87.50	87.50	88.00	88.00
Warp tensile strength in pounds	124.40	123.80	121.20	119.60	117.80	116.80
Percentage increase in warp tensile strength ...	0.90	0.40	-	-	-	-
Percentage decrease in warp tensile strength ...	-	-	1.70	3.00	4.50	5.30
Filling tensile strength in pounds	100.20	98.40	95.60	92.40	90.20	88.40
Percentage decrease in filling tensile strength.	6.90	8.60	11.20	14.10	16.20	17.80
Absorbency index in seconds	3.34	3.72	2.34	2.90	3.46	3.22

EXPERIMENTAL SET II (Experiments 7 to 12)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of two grams of chlorine available per liter. The temperature of treatment was seventy-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	7	8	9	10	11	12
Total loss in pH	0.20	0.40	0.50	0.60	0.60	0.60
Total grams of chlorine used up	0.5325	0.7455	0.8520	1.0650	1.2780	1.3845
Net percent lost in chemicking	0.60	0.60	0.65	0.60	0.65	0.65
Net percent warp shrinkage	3.70	3.60	3.70	3.60	3.80	4.00
Net percent filling shrinkage	2.50	2.60	2.30	2.40	2.50	2.40
Average ends per inch ...	107.00	106.80	107.00	106.80	107.20	107.40
Percent white opacity ...	75.00	76.00	76.50	77.00	77.50	77.50
Percent white shine	87.00	87.50	87.50	88.00	88.50	88.50
Warp tensile strength in pounds	124.20	121.60	118.80	116.60	116.20	114.40
Percentage increase in warp strength	0.70	-	-	-	-	-
Percentage decrease in warp tensile strength ...	-	1.40	3.60	5.40	5.80	7.20
Filling tensile strength in pounds	98.60	95.20	93.40	90.20	87.20	85.60
Percentage decrease in filling strength	8.40	11.50	13.20	16.20	19.00	20.40
Absorbency index in seconds	3.94	3.50	3.36	3.38	3.44	3.28

EXPERIMENTAL SET III (Experiments 13 to 18)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of three grams of chlorine available per liter. The temperature of treatment was seventy-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	13	14	15	16	17	18
Total loss in pH	0.20	0.40	0.50	0.60	0.60	0.60
Total grams of chlorine used up	0.8520	1.1715	1.3845	1.5975	1.7040	1.8105
Net percent lost in chemicking	0.60	0.60	0.65	0.65	0.70	0.70
Net percent warp shrinkage	3.90	3.70	3.70	3.70	3.90	3.80
Net percent filling shrinkage	2.30	2.40	2.40	2.40	2.40	2.50
Average ends per inch ...	107.20	107.00	107.00	107.00	107.20	107.20
Average picks per inch ..	63.40	63.40	63.40	63.40	63.40	63.60
Percent white opacity ...	75.00	75.50	76.00	77.00	77.50	78.00
Percent white shine	87.00	87.50	88.00	88.50	89.00	89.00
Warp tensile strength in pounds	123.20	120.80	117.80	116.40	114.40	114.00
Percentage decrease in warp tensile strength ...	0.10	2.00	4.50	5.60	7.20	7.50
Filling tensile strength in pounds	99.80	96.20	93.40	90.00	86.80	84.40
Percentage decrease in filling tensile strength .	7.20	10.60	15.20	16.40	19.30	21.60
Absorbency index in seconds	4.04	3.84	3.80	3.40	3.62	3.22

EXPERIMENTAL SET IV (Experiments 19 to 24)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of four grams of chlorine available per liter. The temperature of treatment was seventy-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	19	20	21	22	23	24
Total loss in pH	0.20	0.40	0.50	0.60	0.70	0.70
Total grams of chlorine used up	0.8520	1.2780	1.4910	1.5975	1.7040	1.8105
Net percent lost in chemi cking	0.65	0.65	0.65	0.70	0.70	0.75
Net percent warp shrinkage.....	3.80	3.60	3.70	3.80	3.70	4.00
Net percent filling shrinkage	2.40	2.40	2.30	2.30	2.30	2.40
Average ends per inch ...	107.20	106.80	107.00	107.20	107.00	107.40
Average picks per inch ..	63.40	63.40	63.40	63.40	63.40	63.40
Percent white opacity	76.00	77.00	78.00	78.50	79.00	79.50
Percent white shine	88.00	88.50	89.00	89.50	90.00	90.00
Warp tensile strength in pounds	120.00	117.20	115.40	113.60	111.20	109.40
Percentage decrease in warp tensile strength ...	2.70	5.00	6.40	7.90	10.60	11.30
Filling tensile strength in pounds	98.40	95.00	93.20	90.80	87.20	85.60
Percentage decrease in filling tensile strength.	8.60	11.70	13.40	15.60	19.00	20.40
Absorbency index in seconds	3.74	3.08	2.98	2.82	2.78	2.68

EXPERIMENTAL SET V (Experiments 25 to 30)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of five grams of chlorine available per liter. The temperature of treatment was seventy-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	25	26	27	28	29	30
Total loss in pH	0.20	0.40	0.50	0.60	0.70	0.80
Total grams of chlorine used up	1.0650	1.4910	1.7040	1.8105	1.9170	2.0235
Net percent lost in chemicking	0.65	0.65	0.70	0.75	0.75	0.80
Net percent warp shrinkage	3.80	3.70	3.90	3.70	3.80	3.70
Net percent filling shrinkage	2.30	2.30	2.40	2.40	2.40	2.30
Average ends per inch ...	107.20	107.00	107.20	107.00	107.20	107.00
Average picks per inch ..	63.40	63.40	63.40	63.40	63.40	63.40
Percent white opacity ...	77.00	77.50	78.00	78.50	79.00	80.00
Percent white shine.....	87.50	88.00	88.50	89.00	89.50	90.00
Warp tensile strength in pounds	118.60	116.40	114.20	112.40	110.40	107.80
Percentage decrease in warp tensile strength ...	3.80	5.60	7.40	8.80	10.50	11.60
Filling tensile strength in pounds	94.80	90.60	86.40	82.60	80.20	78.40
Percentage decrease in filling tensile strength.	11.90	15.80	19.70	23.20	25.50	27.10
Absorbency index in seconds	3.56	2.78	2.90	2.84	2.68	2.68

EXPERIMENTAL SET VI (Experiments 31 to 36)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of six grams of chlorine available per liter. The temperature of treatment was seventy-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	31	32	33	34	35	36
Total loss in pH	0.20	0.40	0.50	0.60	0.70	0.80
Total grams of chlorine used up	1.2780	1.8105	2.0235	2.1300	2.2365	2.3430
Net percent lost in chemicking	0.75	0.75	0.80	0.85	0.80	0.90
Net percent warp shrinkage	3.90	3.90	3.70	3.90	3.70	3.80
Net percent filling shrinkage	2.30	2.30	2.30	2.40	2.40	2.40
Average ends per inch ...	107.20	107.20	107.00	107.20	107.00	107.20
Average picks per inch ..	63.40	63.20	63.40	63.40	63.40	63.40
Percent white opacity ...	77.50	78.00	78.50	79.00	80.00	79.00
Warp tensile strength in pounds	116.80	113.40	110.20	107.40	104.60	101.20
Percentage decrease in warp tensile strength ...	5.30	8.00	10.60	12.90	15.20	17.90
Filling tensile strength in pounds	91.80	88.60	85.40	82.40	80.00	77.20
Percentage decrease in filling tensile strength.	14.70	17.70	20.60	23.40	25.70	28.30
Absorbency index in seconds	3.16	2.78	2.84	2.74	2.59	2.62

EXPERIMENTAL SET VII (Experiments 37 to 42)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of one gram of chlorine available per liter. The temperature of treatment was ninety-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	37	38	39	40	41	42
Total loss in pH	0.30	0.50	0.70	0.80	0.80	0.80
Total grams of chlorine used up	0.6390	0.8620	0.9585	1.0650	1.1715	1.2780
Net percent lost in chemicking	0.60	0.65	0.60	0.60	0.65	0.65
Net percent warp shrinkage	3.90	3.80	3.80	3.90	4.00	3.80
Net percent filling shrinkage	2.40	2.40	2.40	2.20	2.40	2.60
Average ends per inch ...	107.20	107.00	107.20	107.20	107.40	107.20
Average picks per inch ..	63.40	63.40	63.40	63.20	63.40	63.60
Percent white opacity ...	74.00	74.50	75.00	76.00	76.50	77.00
Percent white shine	88.00	88.50	89.00	89.00	89.50	90.00
Warp tensile strength in pounds	113.20	110.40	106.20	102.40	99.60	96.40
Percentage decrease in warp tensile strength ...	8.20	10.50	13.90	17.00	19.20	21.80
Filling tensile strength in pounds	91.40	87.60	85.40	83.20	80.20	78.40
Percentage decrease in filling tensile strength.	15.10	18.60	20.60	22.70	25.50	27.10
Absorbency index in seconds	3.12	2.70	2.44	2.36	1.98	1.96

EXPERIMENTAL SET VIII (Experiments 43 to 48)

This group of experiments was carried out with a concentration of sodium hydrochlorite bleaching solution of two grams of chlorine available per liter. The temperature of treatment was ninety-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	43	44	45	46	47	48
Total loss in pH	0.30	0.50	0.70	0.80	0.80	0.80
Total grams of chlorine used up	0.9585	1.2780	1.4910	1.5975	1.7040	1.8105
Net percent lost in chemicking	0.60	0.65	0.65	0.65	0.65	0.70
Net percent warp shrinkage	4.00	3.70	3.90	3.90	3.80	3.90
Net percent filling shrinkage	2.30	2.20	2.30	2.30	2.30	2.40
Average ends per inch ...	107.40	107.00	107.20	107.20	107.20	107.20
Average picks per inch ..	63.40	63.20	63.40	63.40	63.40	63.40
Percent white opacity ...	75.50	76.50	77.00	77.50	78.00	78.50
Percent white shine	88.50	89.00	89.50	89.50	90.00	90.50
Warp tensile strength in pounds	112.20	109.60	105.40	100.20	97.40	95.20
Percentage decrease in warp tensile strength ...	9.00	11.10	14.50	18.70	21.00	22.80
Filling tensile strength in pounds	90.20	85.80	81.20	77.40	75.20	71.60
Percentage decrease in filling tensile strength.	16.20	20.30	24.50	28.10	30.10	33.50
Absorbency index in seconds	2.32	1.82	2.04	1.98	1.68	1.68

EXPERIMENTAL SET IX (Experiments 49 to 54)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of three grams of chlorine available per liter. The temperature of treatment was ninety-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	49	50	51	52	53	54
Total loss in Ph	0.30	0.50	0.70	0.80	0.90	0.90
Total grams of chlorine used up	1.2780	1.5975	1.8105	1.9170	2.0235	2.1300
Net percent lost in chemicking	0.60	0.65	0.65	0.70	0.70	0.70
Net percentage warp shrinkage	3.70	3.70	3.60	3.70	3.70	3.80
Net percent filling shrinkage	2.30	2.30	2.40	2.30	2.40	2.30
Average ends per inch ...	107.00	107.00	106.80	107.00	107.00	107.20
Average picks per inch ..	63.40	63.40	63.40	63.20	63.20	63.40
Percent white opacity ...	76.00	76.50	77.00	77.50	78.00	78.00
Percent white shine	88.50	89.00	89.50	90.00	90.50	91.00
Warp tensile strength in pounds	110.40	105.60	101.40	99.20	97.00	94.60
Percentage decrease in warp tensile strength ...	10.50	14.40	17.80	19.50	21.30	23.30
Filling tensile strength in pounds	88.60	83.80	80.20	77.40	74.20	70.20
Percentage decrease in filling tensile strength.	17.70	22.10	25.50	28.10	31.00	34.80
Absorbency index in seconds	2.50	1.82	1.88	1.64	1.84	1.76

EXPERIMENTAL SET X (Experiments 55 to 60)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of four grams of chlorine available per liter. The temperature of treatment was ninety-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	55	56	57	58	59	60
Total loss in pH	0.30	0.50	0.70	0.80	0.90	0.90
Total grams of chlorine used up	1.4910	1.8105	2.0235	2.1300	2.2365	2.3430
Net percent lost in chemicking	0.65	0.65	0.70	0.70	0.75	0.80
Net percent warp shrinkage	3.80	3.90	4.00	3.70	3.90	4.00
Net percent filling shrinkage	2.40	2.40	2.30	2.30	2.30	2.50
Average ends per inch ...	107.20	107.20	107.40	107.00	107.20	107.40
Average picks per inch ..	63.40	63.40	63.40	63.40	63.40	63.60
Percent white opacity ...	76.00	77.00	78.00	79.00	79.50	80.00
Percent white shine	89.00	89.50	89.50	90.00	90.50	91.00
Warp tensile strength in pounds	104.20	100.40	97.20	94.20	91.40	89.20
Percentage decrease in warp tensile strength ...	15.50	18.60	21.20	23.60	25.90	27.70
Filling tensile strength in pounds	86.40	82.20	76.80	72.60	69.60	68.40
Percentage decrease in filling tensile strength.	19.70	23.60	28.60	32.50	35.30	36.40
Absorbency index in seconds	2.30	2.12	2.00	1.86	1.76	1.66

EXPERIMENTAL SET XI (Experiments 61 to 66)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of five grams of chlorine available per liter. The temperature of treatment was ninety-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	61	62	63	64	65	66
Total loss in pH	0.30	0.50	0.70	0.80	0.90	1.00
Total grams of chlorine used up	1.9170	2.2365	2.4495	2.5560	2.6625	2.7690
Net percent lost in chemicking	0.70	0.75	0.70	0.80	0.85	0.85
Net percent warp shrinkage	3.70	3.70	3.70	3.70	3.70	3.70
Net percent filling shrinkage	2.40	2.50	2.30	2.20	2.30	2.40
Average ends per inch ...	107.20	107.00	107.00	107.00	107.00	107.00
Average picks per inch ..	63.40	63.40	63.40	63.20	63.40	63.40
Percent white opacity ...	77.00	77.50	77.00	79.00	80.00	80.50
Percent white shine	89.00	89.50	90.00	89.50	90.50	90.50
Warp tensile strength in pounds	101.60	97.20	93.40	89.20	86.40	84.20
Percentage decrease in warp tensile strength ...	17.60	21.20	24.20	27.70	29.90	31.70
Filling tensile strength in pounds	84.40	80.80	76.20	74.20	71.00	68.20
Percentage decrease in filling tensile strength.	21.60	24.90	29.20	31.00	34.00	36.40
Absorbency index in seconds	2.44	2.36	2.26	2.28	2.38	1.80

EXPERIMENTAL SET XII (Experiments 67 to 72)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of six grams of chlorine available per liter. The temperature of treatment was ninety-six degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	67	68	69	70	71	72
Total loss in pH	0.30	0.50	0.70	0.80	0.90	1.00
Total grams of chlorine used up	2.3430	2.6625	2.8755	2.9820	3.0885	3.1950
Net percent lost in chemicking	0.75	0.80	0.85	0.85	0.90	0.95
Net percent warp shrinkage	3.90	3.70	3.80	3.70	3.80	4.00
Net percent filling shrinkage	2.40	2.40	2.30	2.30	2.40	2.40
Average ends per inch ...	107.20	107.00	107.20	107.00	107.20	107.40
Average picks per inch ..	63.40	63.20	63.40	63.40	63.40	63.60
Percent white opacity ...	78.00	78.00	79.00	80.00	80.00	79.50
Percent white shine	89.00	89.50	90.00	90.00	90.50	90.00
Warp tensile strength in pounds	99.60	95.20	91.80	88.60	85.20	83.40
Percentage decrease in warp tensile strength ...	19.20	22.80	25.50	28.10	30.90	32.40
Filling tensile strength in pounds	81.00	78.80	75.20	71.80	68.20	66.40
Percentage decrease in filling tensile strength.	24.70	26.80	30.10	33.30	36.60	38.30
Absorbency index in seconds	2.78	2.44	2.14	1.86	1.76	1.72

EXPERIMENTAL SET XIII (Experiments 73 to 78)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of one gram of chlorine available per liter. The temperature of treatment was one hundred and sixteen degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	73	74	75	76	77	78
Total loss in pH	0.30	0.60	0.80	0.90	0.90	0.90
Total grams of chlorine used up	0.7455	0.9585	1.0650	1.1715	1.2780	1.3845
Net percent lost in chemicking	0.65	0.65	0.65	0.70	0.70	0.75
Net percent warp shrinkage	3.70	3.90	3.80	3.70	3.90	3.90
Net percent filling shrinkage	2.30	2.40	2.30	2.30	2.40	2.20
Average ends per inch ...	107.00	107.20	107.20	107.00	107.20	107.20
Average picks per inch ..	63.40	63.40	63.40	63.40	63.40	63.20
Percent white opacity ...	75.00	75.50	76.00	77.00	77.50	77.50
Percent white shine	88.00	89.00	89.50	90.00	90.50	91.00
Warp tensile strength in pounds	102.20	100.40	97.20	94.40	90.00	87.20
Percentage decrease in warp tensile strength ...	17.10	18.60	21.20	23.40	27.00	29.30
Filling tensile strength in pounds	85.20	83.40	79.20	77.40	74.60	71.80
Percentage decrease in filling tensile strength.	20.82	22.50	26.40	28.10	30.70	33.30
Absorbency index in seconds	2.46	2.26	1.76	1.54	1.40	1.22

EXPERIMENTAL SET XIV (Experiments 79 to 84)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of two grams of chlorine available per liter. The temperature of treatment was one hundred and sixteen degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	79	80	81	82	83	84
Total loss in pH	0.30	0.60	0.80	0.90	0.90	0.90
Total grams of chlorine used up	1.0650	1.2780	1.4910	1.7040	1.8105	1.9170
Net percent lost in chemicking	0.65	0.70	0.75	0.75	0.80	0.85
Net percent warp shrinkage	3.70	3.70	3.80	3.90	3.70	4.00
Net percent filling shrinkage	2.50	2.40	2.40	2.40	2.50	2.30
Average ends per inch ...	107.00	107.00	107.20	107.20	107.00	107.40
Average picks per inch ..	63.60	63.40	63.40	63.40	63.60	63.40
Percent white opacity ...	76.00	77.00	77.00	77.50	78.00	78.50
Percent white shine	89.00	89.50	90.00	90.50	89.50	90.00
Warp tensile strength in pounds	99.40	95.60	88.20	85.40	82.60	79.20
Percentage decrease in warp tensile strength ...	19.40	22.50	28.50	30.70	33.00	35.80
Filling tensile strength in pounds	83.80	80.60	77.20	74.60	71.20	68.80
Percentage decrease in filling tensile strength.	22.10	25.00	28.30	30.70	33.80	36.10
Absorbency index in seconds	2.14	1.84	1.70	1.36	1.28	1.82

EXPERIMENTAL SET XV (Experiments 85 to 90)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of three grams of chlorine available per liter. The temperature of treatment was one hundred and sixteen degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	85	86	87	88	89	90
Total loss in pH	0.30	0.60	0.80	0.90	1.00	1.00
Total grams of chlorine used up	1.4910	1.8105	1.9170	2.0235	2.1300	2.2365
Net percent lost in chemicking	0.75	0.75	0.80	0.85	0.85	0.90
Net percent warp shrinkage	3.80	3.70	3.70	3.70	4.00	3.80
Net percent filling shrinkage	2.20	2.30	2.30	2.40	2.50	2.40
Average ends per inch ...	107.00	107.00	107.00	107.00	107.40	107.20
Average picks per inch	63.20	63.40	63.40	63.40	63.60	63.40
Percent white opacity ...	77.00	77.50	77.50	78.50	79.00	79.50
Percent white shine	90.00	91.00	91.00	91.50	91.50	92.00
Warp tensile strength in pounds	96.20	90.60	84.40	82.00	80.20	78.40
Percentage decrease in warp tensile strength ...	22.00	26.50	31.50	33.50	35.00	36.40
Filling tensile strength in pounds	82.60	80.20	77.40	74.20	72.60	70.20
Percentage decrease in filling tensile strength.	23.10	25.50	28.10	31.00	32.50	34.80
Absorbency index in seconds	1.52	1.40	1.06	1.04	0.98	0.96

EXPERIMENTAL SET XVI (Experiments 91 to 96)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of four grams of chlorine available per liter. The temperature of treatment was one hundred and sixteen degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	91	92	93	94	95	96
Total loss in pH	0.30	0.60	0.80	0.90	1.00	1.00
Total grams of chlorine used up	1.5975	1.9170	2.1300	2.2365	2.3430	2.4495
Net percent lost in chemicking	0.75	0.80	0.85	0.90	0.95	1.00
Net percent warp shrinkage	3.70	3.60	3.80	3.90	3.70	3.90
Net percent filling shrinkage	2.40	2.20	2.60	2.20	2.40	2.40
Average ends per inch ...	107.00	106.80	107.20	107.20	107.00	107.20
Average picks per inch ..	63.40	63.20	63.60	63.20	63.40	63.40
Percent white opacity ...	77.50	78.00	78.00	79.00	80.00	80.50
Percent white shine	88.00	89.00	90.00	90.50	91.00	91.00
Warp tensile strength in pounds	94.60	89.20	84.60	80.20	76.60	72.40
Percentage decrease in warp tensile strength ...	23.30	27.70	31.40	37.00	37.90	41.30
Filling tensile strength in pounds	84.40	81.20	78.60	75.40	73.40	67.30
Percentage decrease in filling tensile strength.	21.60	24.50	27.00	29.10	31.80	37.50
Absorbency index in seconds	1.82	1.52	1.46	1.40	1.40	1.04

EXPERIMENTAL SET XVII (Experiments 97 to 102)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of five grams of chlorine available per liter. The temperature of treatment was one hundred and sixteen degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	97	98	99	100	101	102
Total loss in pH	0.30	0.60	0.80	0.90	1.00	1.10
Total grams of chlorine used up	2.0235	2.4495	2.5560	2.6625	2.7690	2.8755
Net percent lost in chemicking	0.75	0.70	0.85	0.90	0.95	1.00
Net percent warp shrinkage	3.80	3.80	3.80	3.90	3.70	3.70
Net percent filling shrinkage	2.30	2.30	2.30	2.40	2.30	2.50
Average ends per inch ...	107.20	107.20	107.20	107.20	107.00	107.00
Average picks per inch ..	63.40	63.40	63.40	63.40	63.40	63.60
Percent white opacity ...	77.50	78.00	78.50	80.00	80.50	80.50
Percent white shine	89.00	90.00	90.00	90.50	91.00	91.50
Warp tensile strength in pounds	92.40	87.60	82.40	78.80	73.40	68.20
Percentage decrease in warp tensile strength ...	25.10	29.00	33.20	36.10	40.50	44.70
Filling tensile strength in pounds	80.20	75.60	72.80	68.20	64.40	63.50
Percentage decrease in filling tensile strength.	25.50	29.70	32.30	36.60	40.20	40.70
Absorbency index in seconds	1.60	1.52	1.26	1.12	0.94	0.90

EXPERIMENTAL SET XVIII (Experiments 103 to 108)

This group of experiments was carried out with a concentration of sodium hypochlorite bleaching solution of six grams of chlorine available per liter. The temperature of treatment was one hundred and sixteen degrees Fahrenheit. The lengths of time of treatment varied every fifteen minutes in numerical order from fifteen to ninety minutes.

Experiment No.	103	104	105	106	107	108
Total loss in pH	0.30	0.60	0.80	1.00	1.10	1.20
Total grams of chlorine used up	2.5560	2.8755	3.0885	3.1950	3.015	3.4080
Net percent lost in chemicking	0.80	0.85	0.95	0.95	1.00	1.10
Net percent warp shrinkage	3.70	3.80	3.80	3.70	3.90	3.90
Net percent filling shrinkage	2.50	2.20	2.40	2.40	2.30	2.40
Average ends per inch ...	107.00	107.20	107.20	107.00	107.20	107.20
Average picks per inch ..	63.60	63.20	63.40	63.40	63.40	63.40
Percent white opacity ...	78.50	78.00	79.00	79.50	79.50	80.50
Percent white shine	90.00	90.00	90.50	90.50	91.00	91.00
Warp tensile strength in pounds	90.80	85.40	81.40	77.60	74.20	69.40
Percentage decrease in warp tensile strength ...	26.40	30.70	34.00	37.10	39.80	43.70
Filling tensile strength in pounds	77.20	74.20	68.60	66.20	64.60	62.80
Percentage decrease in filling tensile strength.	28.30	31.00	36.20	38.50	40.00	41.60
Absorbency index in seconds	1.48	1.32	1.10	0.94	0.80	0.88

SECTION III

TABLES AND GRAPHS

Table I: pH Readings in Desizing and Total increase in pH, for Each Run.

Average Results. pH 7.0 at 25°C.

Sample	Run No. 1	Run No. 2	Run No. 3	Average
Original	6.80	6.80	6.80	6.800
15 min.	6.80	6.80	6.80	6.800
30 min.	6.80	6.80	6.80	6.800
45 min.	6.80	6.80	6.80	6.800
60 min.	6.85	6.80	6.80	6.816
75 min.	6.85	6.85	6.85	6.850
90 min.	6.90	6.85	6.85	6.867
105 min.	6.90	6.90	6.85	6.880
120 min.	6.90	6.90	6.90	6.900
Total Increase	0.10	0.10	0.10	0.100

Table II: pH Readings in Kier Boiling and Total Loss in pH for Each Run.

Average Results. pH 7.0 at 25°C.

Sample	Run No. 1	Run No. 2	Run No. 3	Average
Original	11.3	11.4	11.4	11.367
At Pressure	11.3	11.4	11.4	11.367
30 min.	11.3	11.4	11.4	11.367
1.0 hour	11.3	11.4	11.4	11.367
1.5 hours	11.3	11.4	11.4	11.367
2.0 hours	11.3	11.4	11.4	11.367
2.5 hours	11.3	11.4	11.4	11.367
3.0 hours	11.3	11.4	11.4	11.367
3.5 hours	11.3	11.4	11.4	11.367
4.0 hours	11.3	11.4	11.4	11.367
4.5 hours	11.3	11.4	11.4	11.367
5.0 hours	11.3	11.4	11.4	11.367
5.5 hours	11.3	11.4	11.4	11.367
6.0 hours	11.3	11.3	11.4	11.333
6.5 hours	11.2	11.2	11.3	11.233
7.0 hours	11.1	11.2	11.2	11.167
7.5 hours	11.0	11.1	11.1	11.067
8.0 hours	10.9	11.0	11.0	10.967
Total Loss	0.4	0.4	0.4	0.400

Table III: Percentage Shrinkage from Gray to Scoured Fabric.

	Warp				Filling			
Run No.	1	2	3	Av.	1	2	3	Av.
1	9.7	9.8	9.9	9.8	5.5	5.6	5.7	5.6
2	9.5	9.8	9.8	9.7	5.4	5.4	6.7	5.5
3	9.9	10.0	9.8	9.9	5.4	5.3	5.5	5.4
Average				9.8				5.6

Table IV: Loss in Weight from Gray to Desized and Scoured Fabric Per Yard of Material in Grams.

Run No.	Weight in Grams of Gray Fabric	Desized Weight in Grams	Scoured Weight in Grams	Net Percent Size	Gross Percent Loss	Net Percent Removed by Scouring
1	225.1	212.9	197.5	7.7	12.3	4.6
2	235.1	213.3	197.9	7.8	14.8	7.0
3	223.7	210.1	194.9	8.0	12.8	4.8
Average	227.9	212.0	196.8	7.8	13.6	5.8

TABLE V: Tabulation of Conditions Used in Each Chemicking Test.

Experiment No.	Time in Minutes	Concentrations in gms. Cl/lit.	Temperature in degrees F.
1	15	1	76
2	30	1	76
3	45	1	76
4	60	1	76
5	75	1	76
6	90	1	76
7	15	2	76
8	30	2	76
9	45	2	76
10	60	2	76
11	75	2	76
12	90	2	76
13	15	3	76
14	30	3	76
15	45	3	76
16	60	3	76
17	75	3	76
18	90	3	76
19	15	4	76
20	30	4	76
21	45	4	76
22	60	4	76
23	75	4	76
24	90	4	76
25	15	5	76
26	30	5	76
27	45	5	76
28	60	5	76
29	75	5	76
30	90	5	76
31	15	6	76
32	30	6	76
33	45	6	76
34	60	6	76
35	75	6	76
36	90	6	76

Cont.

Table V: Continued

Experiment No.	Time in Minutes	Concentrations in gms. Cl/lit.	Temperature in degrees F.
37	15	1	96
38	30	1	96
39	45	1	96
40	60	1	96
41	75	1	96
42	90	1	96
43	15	2	96
44	30	2	96
45	45	2	96
46	60	2	96
47	75	2	96
48	90	2	96
49	15	3	96
50	30	3	96
51	45	3	96
52	60	3	96
53	75	3	96
54	90	3	96
55	15	4	96
56	30	4	96
57	45	4	96
58	60	4	96
59	75	4	96
60	90	4	96
61	15	5	96
62	30	5	96
63	45	5	96
64	60	5	96
65	75	5	96
66	90	5	96
67	15	6	96
68	30	6	96
69	45	6	96
70	60	6	96
71	75	6	96
72	90	6	96

Cont./

Table V: Continued

Experiment No.	Time in Minutes	Concentrations in gms. Cl/lit.	Temperature in degrees F.
73	15	1	116
74	30	1	116
75	45	1	116
76	60	1	116
77	75	1	116
78	90	1	116
79	15	2	116
80	30	2	116
81	45	2	116
82	60	2	116
83	75	2	116
84	90	2	116
85	15	3	116
86	30	3	116
87	45	3	116
88	60	3	116
89	75	3	116
90	90	3	116
91	15	4	116
92	30	4	116
93	45	4	116
94	60	4	116
95	75	4	116
96	90	4	116
97	15	5	116
98	30	5	116
99	45	5	116
100	60	5	116
101	75	5	116
102	90	5	116
103	15	6	116
104	30	6	116
105	45	6	116
106	60	6	116
107	75	6	116
108	90	6	116

Table VI: pH Readings in Chemicking and Total Loss in pH for Each Experiment. pH 7.0 at 25° C.

Experiment No.	Original Sample	15 min. Sample	30 min. Sample	45 min. Sample	60 min. Sample	75 min. Sample	90 min. Sample	Total Loss in pH
1	10.0	9.8	-	-	-	-	-	0.2
2	10.0	9.8	9.6	-	-	-	-	0.4
3	10.0	9.8	9.6	9.5	-	-	-	0.5
4	10.0	9.8	9.6	9.5	9.5	-	-	0.5
5	10.0	9.8	9.6	9.5	9.5	9.5	-	0.5
6	10.0	9.8	9.6	9.5	9.5	9.5	9.5	0.5
7	10.1	9.9	-	-	-	-	-	0.2
8	10.1	9.9	9.7	-	-	-	-	0.4
9	10.1	9.9	9.7	9.6	-	-	-	0.5
10	10.1	9.9	9.7	9.6	9.5	-	-	0.6
11	10.1	9.9	9.7	9.6	9.5	9.5	-	0.6
12	10.1	9.9	9.7	9.6	9.5	9.5	9.5	0.6
13	10.2	10.0	-	-	-	-	-	0.2
14	10.2	10.0	9.8	-	-	-	-	0.4
15	10.2	10.0	9.8	9.7	-	-	-	0.5
16	10.2	10.0	9.8	9.7	9.6	-	-	0.6
17	10.2	10.0	9.8	9.7	9.6	9.6	-	0.6
18	10.2	10.0	9.8	9.7	9.6	9.6	9.6	0.6
19	10.3	10.1	-	-	-	-	-	0.2
20	10.3	10.1	9.9	-	-	-	-	0.4
21	10.3	10.1	9.9	9.8	-	-	-	0.5
22	10.3	10.1	9.9	9.8	9.7	-	-	0.6
23	10.3	10.1	9.9	9.8	9.7	9.6	-	0.7
24	10.3	10.1	9.9	9.8	9.7	9.6	9.6	0.7
25	10.4	10.2	-	-	-	-	-	0.2
26	10.4	10.2	10.0	-	-	-	-	0.4
27	10.4	10.2	10.0	9.9	-	-	-	0.5
28	10.4	10.2	10.0	9.9	9.8	-	-	0.6
29	10.4	10.2	10.0	9.9	9.8	9.7	-	0.7
30	10.4	10.2	10.0	9.9	9.8	9.7	9.6	0.8
31	10.5	10.3	-	-	-	-	-	0.2
32	10.5	10.3	10.1	-	-	-	-	0.4
33	10.5	10.3	10.1	10.0	-	-	-	0.5
34	10.5	10.3	10.1	10.0	9.9	-	-	0.6
35	10.5	10.3	10.1	10.0	9.9	9.8	-	0.7
36	10.5	10.3	10.1	10.0	9.9	9.8	9.7	0.8

Cont.

Table VI: Continued

Experiment No.	Original Sample	15 min. Sample	30 min. Sample	45 min. Sample	60 min. Sample	75 min. Sample	90 min. Sample	Total Loss in pH
37	10.0	9.7	-	-	-	-	-	0.3
38	10.0	9.7	9.5	-	-	-	-	0.5
39	10.0	9.7	9.5	9.3	-	-	-	0.7
40	10.0	9.7	9.5	9.3	9.2	-	-	0.8
41	10.0	9.7	9.5	9.3	9.2	9.2	-	0.8
42	10.0	9.7	9.5	9.3	9.2	9.2	9.2	0.8
43	10.1	9.8	-	-	-	-	-	0.3
44	10.1	9.8	9.6	-	-	-	-	0.5
45	10.1	9.8	9.6	9.4	-	-	-	0.7
46	10.1	9.8	9.6	9.4	9.3	-	-	0.8
47	10.1	9.8	9.6	9.4	9.3	9.3	-	0.8
48	10.1	9.8	9.6	9.4	9.3	9.3	9.3	0.8
49	10.2	9.9	-	-	-	-	-	0.3
50	10.2	9.9	9.7	-	-	-	-	0.5
51	10.2	9.9	9.7	9.5	-	-	-	0.7
52	10.2	9.9	9.7	9.5	9.4	-	-	0.8
53	10.2	9.9	9.7	9.5	9.4	9.3	-	0.9
54	10.2	9.9	9.7	9.5	9.4	9.3	9.3	0.9
55	10.3	10.0	-	-	-	-	-	0.3
56	10.3	10.0	9.8	-	-	-	-	0.5
57	10.3	10.0	9.8	9.6	-	-	-	0.7
58	10.3	10.0	9.8	9.6	9.5	-	-	0.8
59	10.3	10.0	9.8	9.6	9.5	9.4	-	0.9
60	10.3	10.0	9.8	9.6	9.5	9.4	9.4	0.9
61	10.4	10.1	-	-	-	-	-	0.3
62	10.4	10.1	9.9	-	-	-	-	0.5
63	10.4	10.1	9.9	9.7	-	-	-	0.7
64	10.4	10.1	9.9	9.7	9.6	-	-	0.8
65	10.4	10.1	9.9	9.7	9.6	9.5	-	0.9
66	10.4	10.1	9.9	9.7	9.6	9.5	9.4	1.0
67	10.5	10.2	-	-	-	-	-	0.3
68	10.5	10.2	10.0	-	-	-	-	0.5
69	10.5	10.2	10.0	9.8	-	-	-	0.7
70	10.5	10.2	10.0	9.8	9.7	-	-	0.8
71	10.5	10.2	10.0	9.8	9.7	9.6	-	0.9
72	10.5	10.2	10.0	9.8	9.7	9.6	9.5	1.0

Cont.

Table VI: Continued

Experiment No.	Original Sample	15 min. Sample	30 min. Sample	45 min. Sample	60 min. Sample	75 min. Sample	90 min. Sample	Total Loss in pH
73	10.0	9.7	-	-	-	-	-	0.3
74	10.0	9.7	9.4	-	-	-	-	0.6
75	10.0	9.7	9.4	9.2	-	-	-	0.8
76	10.0	9.7	9.4	9.2	9.1	-	-	0.9
77	10.0	9.7	9.4	9.2	9.1	9.1	-	0.9
78	10.0	9.7	9.4	9.2	9.1	9.1	9.1	0.9
79	10.1	9.8	-	-	-	-	-	0.3
80	10.1	9.8	9.5	-	-	-	-	0.6
81	10.1	9.8	9.5	9.3	-	-	-	0.8
82	10.1	9.8	9.5	9.3	9.2	-	-	0.9
83	10.1	9.8	9.5	9.3	9.2	9.2	-	0.9
84	10.1	9.8	9.5	9.3	9.2	9.2	9.2	0.9
85	10.2	9.9	-	-	-	-	-	0.3
86	10.2	9.9	9.6	-	-	-	-	0.6
87	10.2	9.9	9.6	9.4	-	-	-	0.8
88	10.2	9.9	9.6	9.4	9.3	-	-	0.9
89	10.2	9.9	9.6	9.4	9.3	9.2	-	1.0
90	10.2	9.9	9.6	9.4	9.3	9.2	9.2	1.0
91	10.3	10.0	-	-	-	-	-	0.3
92	10.3	10.0	9.7	-	-	-	-	0.6
93	10.3	10.0	9.7	9.5	-	-	-	0.8
94	10.3	10.0	9.7	9.5	9.4	-	-	0.9
95	10.3	10.0	9.7	9.5	9.4	9.3	-	1.0
96	10.3	10.0	9.7	9.5	9.4	9.3	9.3	1.0
97	10.4	10.1	-	-	-	-	-	0.3
98	10.4	10.1	9.8	-	-	-	-	0.6
99	10.4	10.1	9.8	9.6	-	-	-	0.8
100	10.4	10.1	9.8	9.6	9.5	-	-	0.9
101	10.4	10.1	9.8	9.6	9.5	9.4	-	1.0
102	10.4	10.1	9.8	9.6	9.5	9.4	9.3	1.1
103	10.5	10.2	-	-	-	-	-	0.3
104	10.5	10.2	9.9	-	-	-	-	0.6
105	10.5	10.2	9.9	9.7	-	-	-	0.8
106	10.5	10.2	9.9	9.7	9.5	-	-	1.0
107	10.5	10.2	9.9	9.7	9.5	9.4	-	1.1
108	10.5	10.2	9.9	9.7	9.5	9.4	9.3	1.2

Table VII: Titration of Sodium Hypochlorite Solutions with Sodium Thiosulphate in Milliliters per Five-Milliliter Sample

Experiment No.	Original Sample	15 min. Sample	30 min. Sample	45 min. Sample	60 min. Sample	75 min. Sample	90 min. Sample	Total Difference
1	1.40	1.25	-	-	-	-	-	0.15
2	1.40	1.25	1.20	-	-	-	-	0.20
3	1.40	1.25	1.20	1.15	-	-	-	0.25
4	1.40	1.25	1.20	1.15	1.10	-	-	0.30
5	1.40	1.25	1.20	1.15	1.10	1.05	-	0.35
6	1.40	1.25	1.20	1.15	1.10	1.05	1.00	0.40
7	2.80	2.55	-	-	-	-	-	0.25
8	2.80	2.55	2.45	-	-	-	-	0.35
9	2.80	2.55	2.45	2.40	-	-	-	0.40
10	2.80	2.55	2.45	2.40	2.30	-	-	0.50
11	2.80	2.55	2.45	2.40	2.30	2.20	-	0.60
12	2.80	2.55	2.45	2.40	2.30	2.20	2.15	0.65
13	4.20	3.80	-	-	-	-	-	0.40
14	4.20	3.80	3.65	-	-	-	-	0.55
15	4.20	3.80	3.65	3.55	-	-	-	0.65
16	4.20	3.80	3.65	3.55	3.45	-	-	0.75
17	4.20	3.80	3.65	3.55	3.45	3.40	-	0.80
18	4.20	3.80	3.65	3.55	3.45	3.40	3.35	0.85
19	5.60	5.20	-	-	-	-	-	0.40
20	5.60	5.20	5.00	-	-	-	-	0.60
21	5.60	5.20	5.00	4.90	-	-	-	0.70
22	5.60	5.20	5.00	4.90	4.85	-	-	0.75
23	5.60	5.20	5.00	4.90	4.85	4.80	-	0.80
24	5.60	5.20	5.00	4.90	4.85	4.80	4.75	0.85
25	7.00	6.50	-	-	-	-	-	0.50
26	7.00	6.50	6.30	-	-	-	-	0.70
27	7.00	6.50	6.30	6.20	-	-	-	0.80
28	7.00	6.50	6.30	6.20	6.15	-	-	0.85
29	7.00	6.50	6.30	6.20	6.15	6.10	-	0.90
30	7.00	6.50	6.30	6.20	6.15	6.10	6.05	0.95
31	8.45	7.85	-	-	-	-	-	0.60
32	8.45	7.85	7.60	-	-	-	-	0.85
33	8.45	7.85	7.60	7.50	-	-	-	0.95
34	8.45	7.85	7.60	7.50	7.45	-	-	1.00
35	8.45	7.85	7.60	7.50	7.45	7.40	-	1.05
36	8.45	7.85	7.60	7.50	7.45	7.40	7.35	1.10

Cont.

Table VII: Continued

Experiment No.	Original Sample	15 min. Sample	30 min. Sample	45 min. Sample	60 min. Sample	75 min. Sample	90 min. Sample	Total Difference
37	1.40	1.10	-	-	-	-	-	0.30
38	1.40	1.10	1.00	-	-	-	-	0.40
39	1.40	1.10	1.00	0.95	-	-	-	0.45
40	1.40	1.10	1.00	0.95	0.90	-	-	0.50
41	1.40	1.10	1.00	0.95	0.90	0.85	-	0.55
42	1.40	1.10	1.00	0.95	0.90	0.85	0.80	0.60
43	2.80	2.35	-	-	-	-	-	0.45
44	2.80	2.35	2.20	-	-	-	-	0.60
45	2.80	2.35	2.20	2.10	-	-	-	0.70
46	2.80	2.35	2.20	2.10	2.05	-	-	0.75
47	2.80	2.35	2.20	2.10	2.05	2.00	-	0.80
48	2.80	2.35	2.20	2.10	2.05	2.00	1.95	0.85
49	4.20	3.60	-	-	-	-	-	0.60
50	4.20	3.60	3.45	-	-	-	-	0.75
51	4.20	3.60	3.45	3.35	-	-	-	0.85
52	4.20	3.60	3.45	3.35	3.30	-	-	0.90
53	4.20	3.60	3.45	3.35	3.30	3.25	-	0.95
54	4.20	3.60	3.45	3.35	3.30	3.25	3.20	1.00
55	5.60	4.90	-	-	-	-	-	0.70
56	5.60	4.90	4.75	-	-	-	-	0.85
57	5.60	4.90	4.75	4.65	-	-	-	0.95
58	5.60	4.90	4.75	4.65	4.60	-	-	1.00
59	5.60	4.90	4.75	4.65	4.60	4.55	-	1.05
60	5.60	4.90	4.75	4.65	4.60	4.55	4.50	1.10
61	7.00	6.10	-	-	-	-	-	0.90
62	7.00	6.10	5.95	-	-	-	-	1.05
63	7.00	6.10	5.95	5.85	-	-	-	1.15
64	7.00	6.10	5.95	5.85	5.80	-	-	1.20
65	7.00	6.10	5.95	5.85	5.80	5.75	-	1.25
66	7.00	6.10	5.95	5.85	5.80	5.75	5.70	1.30
67	8.45	7.35	-	-	-	-	-	1.10
68	8.45	7.35	7.20	-	-	-	-	1.25
69	8.45	7.35	7.20	7.10	-	-	-	1.35
70	8.45	7.35	7.20	7.10	7.05	-	-	1.40
71	8.45	7.35	7.20	7.10	7.05	7.00	-	1.45
72	8.45	7.35	7.20	7.10	7.05	7.00	6.95	1.50

Cont.

Table VII: Continued

Experiment No.	Original Sample	15 min. Sample	30 min. Sample	45 min. Sample	60 min. Sample	75 min. Sample	90 min. Sample	Total Difference
73	1.40	1.05	-	-	-	-	-	0.35
74	1.40	1.05	0.95	-	-	-	-	0.45
75	1.40	1.05	0.95	0.90	-	-	-	0.50
76	1.40	1.05	0.95	0.90	0.85	-	-	0.55
77	1.40	1.05	0.95	0.90	0.85	0.80	-	0.60
78	1.40	1.05	0.95	0.90	0.85	0.80	0.75	0.65
79	2.80	2.30	-	-	-	-	-	0.50
80	2.80	2.30	2.20	-	-	-	-	0.60
81	2.80	2.30	2.20	2.10	-	-	-	0.70
82	2.80	2.30	2.20	2.10	2.00	-	-	0.80
83	2.80	2.30	2.20	2.10	2.00	1.95	-	0.85
84	2.80	2.30	2.20	2.10	2.00	1.95	1.90	0.90
85	4.20	3.50	-	-	-	-	-	0.70
86	4.20	3.50	3.35	-	-	-	-	0.85
87	4.20	3.50	3.35	3.30	-	-	-	0.90
88	4.20	3.50	3.35	3.30	3.25	-	-	0.95
89	4.20	3.50	3.35	3.30	3.25	3.20	-	1.00
90	4.20	3.50	3.35	3.30	3.25	3.20	3.15	1.05
91	5.60	4.85	-	-	-	-	-	0.75
92	5.60	4.85	4.70	-	-	-	-	0.90
93	5.60	4.85	4.70	4.60	-	-	-	1.00
94	5.60	4.85	4.70	4.60	4.55	-	-	1.05
95	5.60	4.85	4.70	4.60	4.55	4.50	-	1.10
96	5.60	4.85	4.70	4.60	4.55	4.50	4.45	1.15
97	7.00	6.05	-	-	-	-	-	0.95
98	7.00	6.05	5.85	-	-	-	-	1.15
99	7.00	6.05	5.85	5.80	-	-	-	1.20
100	7.00	6.05	5.85	5.80	5.75	-	-	1.25
101	7.00	6.05	5.85	5.80	5.75	5.70	-	1.30
102	7.00	6.05	5.85	5.80	5.75	5.70	5.65	1.35
103	8.45	7.25	-	-	-	-	-	1.20
104	8.45	7.25	7.10	-	-	-	-	1.35
105	8.45	7.25	7.10	7.00	-	-	-	1.45
106	8.45	7.25	7.10	7.00	6.95	-	-	1.50
107	8.45	7.25	7.10	7.00	6.95	6.90	-	1.55
108	8.45	7.25	7.10	7.00	6.96	6.90	6.85	1.60

Table VIII: Amount of Chlorine Used Up By Each Experiment in the Chemick Treatment of 15 to 1 Ratio of Liquor to Material

Experiment No.	Grams Cl.	Experiment No.	Grams Cl.	Experiment No.	Grams Cl.
1	0.3195	37	0.6390	73	0.7455
2	0.4260	38	0.8520	74	0.9585
3	0.5325	39	0.9585	75	1.0650
4	0.6390	40	1.0650	76	1.1715
5	0.7455	41	1.1715	77	1.2780
6	0.8520	42	1.2780	78	1.3845
7	0.5325	43	0.9585	79	1.0650
8	0.7455	44	1.2780	80	1.2780
9	0.8520	45	1.4910	81	1.4910
10	1.0650	46	1.5975	82	1.7040
11	1.2780	47	1.7040	83	1.8105
12	1.3845	48	1.8105	84	1.9170
13	0.8520	49	1.2780	85	1.4910
14	1.1715	50	1.5975	86	1.8105
15	1.3845	51	1.8105	87	1.9170
16	1.5975	52	1.9170	88	2.0235
17	1.7040	53	2.0235	89	2.1300
18	1.8105	54	2.1300	90	2.2365
19	0.8520	55	1.4910	91	1.5975
20	1.2780	56	1.8105	92	1.9170
21	1.4910	57	2.0235	93	2.1300
22	1.5975	58	2.1300	94	2.2365
23	1.7040	59	2.2365	95	2.3430
24	1.8105	60	2.3430	96	2.4495
25	1.0650	61	1.9170	97	2.0235
26	1.4910	62	2.2365	98	2.4495
27	1.7040	63	2.4495	99	2.5560
28	1.8105	64	2.5560	100	2.6625
29	1.9170	65	2.6625	101	2.7690
30	2.0235	66	2.7690	102	2.8755
31	1.2780	67	2.3430	103	2.5560
32	1.8105	68	2.6625	104	2.8755
33	2.0235	69	2.8755	105	3.0885
34	2.1300	70	2.9820	106	3.1950
35	2.2365	71	3.0885	107	3.3015
36	2.3430	72	3.1950	108	3.4080

Table IX: pH Readings in Antichlor Treatment with Sodium Thiosulphate pH 7.0 at 25° C.

Experiment No.	Original Sample	15 Min. Sample	30 Min. Sample	Total Loss in pH
1	8.50	8.70	8.20	0.30
2	8.50	8.70	8.20	0.30
3	8.45	8.70	8.15	0.30
4	8.50	8.70	8.15	0.35
5	8.50	8.65	8.15	0.35
6	8.55	8.65	8.20	0.35
7	8.50	8.70	8.20	0.30
8	8.45	8.70	8.15	0.30
9	8.45	8.65	8.15	0.30
10	8.45	8.65	8.10	0.30
11	8.50	8.65	8.15	0.35
12	8.50	8.60	8.15	0.35
13	8.50	8.65	8.20	0.30
14	8.50	8.70	8.20	0.30
15	8.50	8.65	8.20	0.30
16	8.55	8.70	8.25	0.30
17	8.55	8.65	8.20	0.35
18	8.55	8.60	8.25	0.30
19	8.50	8.70	8.20	0.30
20	8.50	8.70	8.20	0.30
21	8.50	8.60	8.20	0.30
22	8.55	8.65	8.20	0.35
23	8.40	8.55	8.05	0.35
24	8.40	8.50	8.05	0.35
25	8.45	8.60	8.15	0.30
26	8.40	8.60	8.10	0.30
27	8.50	8.70	8.15	0.35
28	8.50	8.65	8.15	0.35
29	8.50	8.60	8.15	0.35
30	8.50	8.60	8.15	0.35
31	8.50	8.70	8.20	0.30
32	8.50	8.65	8.15	0.35
33	8.50	8.65	8.15	0.35
34	8.50	8.60	8.15	0.35
35	8.40	8.50	8.05	0.35
36	8.50	8.70	8.15	0.35

Table IX: Continued

Experiment No.	Original Sample	15 Min. Sample	30 Min. Sample	Total Loss in pH
37	8.50	8.70	8.20	0.30
38	8.55	8.65	8.25	0.30
39	8.40	8.55	8.10	0.30
40	8.40	8.60	8.10	0.30
41	8.40	8.60	8.05	0.35
42	8.40	8.60	8.05	0.35
43	8.50	8.65	8.20	0.30
44	8.45	8.60	8.15	0.30
45	8.45	8.60	8.15	0.30
46	8.40	8.65	8.05	0.35
47	8.50	8.70	8.15	0.35
48	8.50	8.65	8.15	0.35
49	8.55	8.70	8.25	0.30
50	8.55	8.70	8.25	0.30
51	8.50	8.65	8.15	0.35
52	8.50	8.70	8.15	0.35
53	8.50	8.70	8.15	0.35
54	8.50	8.70	8.15	0.35
55	8.50	8.65	8.20	0.30
56	8.50	8.65	8.20	0.30
57	8.55	8.65	8.20	0.35
58	8.40	8.60	8.05	0.35
59	8.45	8.65	8.10	0.35
60	8.40	8.60	8.05	0.35
61	8.50	8.70	8.20	0.30
62	8.50	8.70	8.15	0.35
63	8.55	8.70	8.20	0.35
64	8.50	8.65	8.15	0.35
65	8.50	8.65	8.15	0.35
66	8.45	8.60	8.10	0.35
67	8.45	8.60	8.15	0.30
68	8.50	8.65	8.20	0.30
69	8.50	8.65	8.15	0.35
70	8.55	8.65	8.20	0.35
71	8.55	8.70	8.15	0.35
72	8.55	8.70	8.20	0.35

Cont.

Table IX: Continued

Experiment No.	Original Sample	15 Min. Sample	30 Min. Sample	Total Loss in pH
73	8.50	8.65	8.20	0.30
74	8.50	8.65	8.20	0.30
75	8.40	8.55	8.10	0.30
76	8.45	8.60	8.10	0.35
77	8.45	8.60	8.10	0.35
78	8.40	8.55	8.05	0.35
79	8.50	8.60	8.20	0.30
80	8.50	8.70	8.20	0.30
81	8.50	8.70	8.20	0.30
82	8.55	8.70	8.20	0.35
83	8.50	8.70	8.15	0.35
84	8.45	8.65	8.10	0.35
85	8.50	8.70	8.20	0.30
86	8.50	8.70	8.20	0.30
87	8.40	8.60	8.05	0.35
88	8.40	8.60	8.05	0.35
89	8.45	8.55	8.10	0.35
90	8.45	8.65	8.10	0.35
91	8.45	8.65	8.15	0.30
92	8.50	8.70	8.20	0.30
93	8.55	8.70	8.20	0.35
94	8.55	8.70	8.20	0.35
95	8.50	8.70	8.15	0.35
96	8.55	8.65	8.20	0.35
97	8.40	8.60	8.10	0.30
98	8.40	8.60	8.10	0.30
99	8.50	8.70	8.15	0.35
100	8.45	8.65	8.10	0.35
101	8.45	8.65	8.10	0.35
102	8.50	8.70	8.15	0.35
103	8.50	8.70	8.20	0.30
104	8.50	8.70	8.15	0.35
105	8.50	8.70	8.15	0.35
106	8.50	8.65	8.15	0.35
107	8.50	8.65	8.15	0.35
108	8.50	8.70	8.15	0.35

Table X: Loss in Weight during Bleaching from Scoured Fabric.

Experiment No.	Scoured Weight (gms)	Bleached Weight (gms)	Loss in Weight (gms)	Percent Loss
1	223.0	221.9	1.1	0.50
2	227.6	226.4	1.2	0.55
3	223.3	222.0	1.3	0.60
4	218.7	217.5	1.2	0.55
5	228.0	226.6	1.4	0.60
6	220.8	219.4	1.4	0.65
7	221.0	219.7	1.3	0.60
8	224.0	222.7	1.3	0.60
9	218.9	217.5	1.4	0.65
10	230.6	229.2	1.4	0.60
11	227.6	226.1	1.5	0.65
12	228.8	227.3	1.5	0.65
13	232.9	231.5	1.4	0.60
14	232.8	231.4	1.4	0.60
15	224.4	223.0	1.4	0.65
16	233.0	231.5	1.5	0.65
17	231.6	230.0	1.6	0.70
18	217.5	216.0	1.5	0.70
19	218.4	217.0	1.4	0.65
20	224.4	222.9	1.5	0.65
21	222.3	220.9	1.4	0.65
22	220.1	218.6	1.5	0.70
23	221.5	220.0	1.5	0.70
24	223.2	221.5	1.7	0.75
25	213.5	212.1	1.4	0.65
26	226.9	225.4	1.5	0.65
27	220.2	218.7	1.5	0.70
28	218.6	217.0	1.6	0.75
29	220.0	218.4	1.6	0.75
30	219.4	217.7	1.7	0.80
31	218.6	217.0	1.6	0.75
32	215.8	214.2	1.6	0.75
33	217.1	215.4	1.7	0.80
34	220.1	218.3	1.8	0.85
35	226.0	224.2	1.8	0.80
36	227.3	225.3	2.0	0.90

Cont.

Table X: Continued

Experiment No.	Scoured Weight (gms)	Bleached Weight (gms)	Loss in Weight (gms)	Percent Loss
37	203.5	202.3	1.2	0.60
38	211.4	210.1	1.3	0.65
39	208.9	207.7	1.2	0.60
40	208.1	206.9	1.2	0.60
41	218.7	217.3	1.4	0.65
42	224.3	222.8	1.5	0.65
43	211.8	210.5	1.3	0.60
44	205.4	204.1	1.3	0.65
45	209.7	208.4	1.3	0.65
46	206.9	205.6	1.3	0.65
47	209.8	208.5	1.3	0.65
48	214.7	213.2	1.5	0.70
49	210.6	209.3	1.3	0.60
50	209.9	208.5	1.4	0.65
51	206.1	204.8	1.3	0.65
52	209.4	207.9	1.5	0.70
53	208.8	207.3	1.5	0.70
54	213.0	211.5	1.5	0.70
55	203.4	202.1	1.3	0.65
56	207.7	206.3	1.4	0.65
57	217.2	215.7	1.5	0.70
58	208.7	207.2	1.5	0.70
59	205.6	204.1	1.5	0.75
60	212.2	210.5	1.7	0.80
61	209.8	208.3	1.5	0.70
62	210.3	208.7	1.6	0.75
63	204.1	202.7	1.4	0.70
64	214.1	212.4	1.7	0.80
65	209.6	207.8	1.8	0.85
66	211.8	210.0	1.8	0.85
67	203.5	201.8	1.7	0.75
68	214.8	213.1	1.7	0.80
69	202.5	200.8	1.7	0.85
70	213.6	211.8	1.8	0.85
71	211.7	209.8	1.9	0.90
72	212.3	210.3	2.0	0.95

Cont.

Table X: Continued

Experiment No.	Scoured Weight (gms)	Bleached Weight (gms)	Loss in Weight (gms)	Percent Loss
73	213.3	211.9	1.4	0.65
74	202.7	201.4	1.3	0.65
75	202.3	201.0	1.3	0.65
76	197.2	195.8	1.4	0.70
77	201.6	200.2	1.4	0.70
78	199.7	198.2	1.5	0.75
79	206.5	205.2	1.3	0.65
80	205.0	203.6	1.4	0.70
81	200.6	199.1	1.5	0.75
82	197.9	196.4	1.5	0.75
83	208.1	206.4	1.7	0.80
84	204.1	202.4	1.7	0.85
85	197.6	196.1	1.5	0.75
86	205.8	204.3	1.5	0.75
87	208.5	206.8	1.7	0.80
88	205.5	204.8	1.7	0.85
89	202.6	200.9	1.7	0.85
90	208.5	206.6	1.9	0.90
91	201.9	200.4	1.5	0.75
92	199.5	197.9	1.6	0.80
93	206.8	205.0	1.8	0.85
94	199.4	197.6	1.8	0.90
95	208.1	206.1	2.0	0.95
96	204.4	202.4	2.0	1.00
97	198.0	196.5	1.5	0.75
98	204.7	203.3	1.4	0.70
99	207.7	205.9	1.8	0.85
100	207.3	205.4	1.9	0.90
101	200.3	198.4	1.9	0.95
102	202.7	200.7	2.0	1.00
103	192.6	191.1	1.5	0.80
104	204.4	202.7	1.7	0.85
105	203.1	201.2	1.9	0.95
106	207.5	205.5	2.0	0.95
107	203.6	201.6	2.0	1.00
108	200.6	198.4	2.2	1.10

Table XI: Percentage of Shrinkage from Scoured to Bleached Fabric

Experiment No.	Warp				Filling			
	1	2	3	Average	1	2	3	Average
1	4.0	3.8	3.9	3.9	2.3	2.4	2.5	2.4
2	3.9	3.9	3.7	3.8	2.5	2.3	2.4	2.4
3	4.0	4.1	3.9	4.0	2.3	2.4	2.2	2.3
4	4.0	4.0	4.0	4.0	2.4	2.5	2.3	2.4
5	3.9	4.0	3.8	3.9	2.2	2.2	2.2	2.2
6	3.9	3.7	3.8	3.8	2.6	2.2	2.4	2.4
7	3.9	3.8	3.6	3.7	2.4	2.5	2.6	2.5
8	3.7	3.7	3.5	3.6	2.7	2.5	2.6	2.6
9	3.6	3.9	3.6	3.7	2.3	2.3	2.3	2.3
10	3.8	3.5	3.5	3.6	2.4	2.4	2.4	2.4
11	3.8	3.8	3.8	3.8	2.5	2.5	2.5	2.5
12	4.1	4.0	3.9	4.0	2.2	2.6	2.4	2.4
13	3.8	4.0	3.9	3.9	2.2	2.7	2.0	2.3
14	3.3	4.1	3.7	3.7	2.3	2.3	2.6	2.4
15	3.7	3.9	3.5	3.7	2.4	2.4	2.4	2.4
16	3.8	3.8	3.5	3.7	2.5	2.5	2.2	2.4
17	3.7	4.1	3.9	3.9	2.5	2.4	2.3	2.4
18	3.8	3.8	3.8	3.8	2.5	2.6	2.4	2.5
19	3.9	3.9	3.6	3.8	2.0	2.7	2.5	2.4
20	3.6	3.7	3.5	3.6	2.3	2.4	2.5	2.4
21	3.8	3.6	3.7	3.7	2.1	2.4	2.4	2.3
22	3.9	3.7	3.8	3.8	2.3	2.3	2.3	2.3
23	3.7	3.7	3.7	3.7	2.2	2.5	2.2	2.3
24	4.0	4.1	3.9	4.0	2.3	2.4	2.5	2.4
25	3.7	3.9	3.8	3.8	2.2	2.5	2.2	2.3
26	3.8	3.7	3.6	3.7	2.2	2.4	2.3	2.3
27	3.9	3.9	3.9	3.9	2.4	2.4	2.4	2.4
28	3.6	3.8	3.7	3.7	2.5	2.3	2.4	2.4
29	4.0	3.7	3.7	3.8	2.6	2.1	2.5	2.4
30	3.7	3.9	3.5	3.7	2.6	2.2	2.1	2.3
31	3.8	4.0	3.9	3.9	2.1	2.5	2.3	2.3
32	3.9	3.9	3.9	3.9	2.4	2.4	2.1	2.3
33	3.6	3.8	3.7	3.7	2.3	2.4	2.2	2.3
34	4.0	3.9	3.8	3.9	2.4	2.5	2.3	2.4
35	3.7	3.5	3.9	3.7	2.5	2.3	2.4	2.4
36	3.9	3.7	3.8	3.8	2.4	2.3	2.5	2.4

Cont.

Table XI: Continued

Experiment No.	Warp 1	2	3	Average	Filling 1	2	3	Average
37	3.9	3.8	4.0	3.9	2.4	2.5	2.3	2.4
38	3.7	3.6	3.8	3.7	2.5	2.3	2.4	2.4
39	3.7	3.9	3.9	3.8	2.4	2.3	2.5	2.4
40	3.8	4.0	3.9	3.9	2.2	2.0	2.4	2.2
41	3.9	4.1	4.0	4.0	2.5	2.2	2.5	2.4
42	3.7	3.8	3.9	3.8	2.5	2.7	2.6	2.6
43	4.0	4.0	4.0	4.0	2.3	2.2	2.4	2.3
44	3.7	3.7	3.7	3.7	2.4	2.0	2.2	2.2
45	3.8	4.0	3.9	3.9	2.2	2.3	2.4	2.3
46	3.7	4.1	3.9	3.9	2.3	2.6	2.3	2.4
47	3.8	3.7	3.9	3.8	2.2	2.2	2.5	2.3
48	3.8	4.0	4.0	3.9	2.4	2.4	2.4	2.4
49	3.7	3.8	3.6	3.7	2.3	2.1	2.5	2.3
50	3.7	3.6	3.8	3.7	2.2	2.6	2.1	2.3
51	3.5	3.5	3.8	3.6	2.4	2.6	2.5	2.4
52	3.9	3.5	3.7	3.7	2.4	2.5	2.0	2.3
53	3.7	4.1	3.3	3.7	2.3	2.6	2.3	2.4
54	3.8	3.7	3.9	3.8	2.4	2.4	2.1	2.3
55	3.8	3.8	3.8	3.8	2.4	2.3	2.5	2.4
56	3.9	3.8	4.0	3.9	2.5	2.3	2.4	2.4
57	3.9	4.0	4.1	4.0	2.3	2.4	2.2	2.3
58	3.6	3.8	3.7	3.7	2.1	2.4	2.4	2.3
59	3.9	4.0	3.8	3.9	2.3	2.5	2.1	2.3
60	3.9	4.0	4.1	4.0	2.5	2.6	2.4	2.5
61	3.7	3.9	3.5	3.7	2.6	2.1	2.5	2.4
62	3.7	3.8	3.6	3.7	2.5	2.5	2.5	2.5
63	3.5	3.8	3.8	3.7	2.5	2.2	2.2	2.3
64	3.7	3.6	3.8	3.7	2.2	2.1	2.3	2.2
65	3.7	3.9	3.5	3.7	2.2	2.4	2.3	2.3
66	3.7	3.7	3.7	3.7	2.5	2.3	2.4	2.4
67	3.7	4.1	3.9	3.9	2.1	2.5	2.6	2.4
68	3.5	3.8	3.8	3.7	2.3	2.4	2.5	2.4
69	3.9	3.6	3.9	3.8	2.1	2.4	2.4	2.3
70	3.6	3.9	3.6	3.7	2.3	2.3	2.3	2.3
71	3.8	3.7	3.9	3.8	2.6	2.2	2.4	2.4
72	4.0	4.0	4.0	4.0	2.5	2.3	2.4	2.4

Cont.

Table XI: Continued

Experiment No.	Warp 1	Warp 2	Warp 3	Warp Average	Filling 1	Filling 2	Filling 3	Filling Average
73	3.8	3.7	3.9	3.7	2.3	2.4	2.2	2.3
74	3.9	4.0	3.8	3.9	2.5	2.3	2.4	2.4
75	3.9	3.8	3.7	3.8	2.3	2.3	2.3	2.3
76	3.7	3.7	3.7	3.7	2.2	2.4	2.3	2.3
77	3.9	4.1	3.7	3.9	2.5	2.3	2.4	2.4
78	4.0	4.0	3.8	3.9	2.2	2.0	2.4	2.2
79	3.8	3.6	3.7	3.7	2.4	2.6	2.5	2.5
80	3.7	3.5	3.9	3.7	2.2	2.5	2.5	2.4
81	3.9	3.7	3.8	3.8	2.3	2.3	2.6	2.4
82	4.0	3.8	3.9	3.9	2.4	2.4	2.4	2.4
83	3.8	3.6	3.7	3.7	2.5	2.4	2.6	2.5
84	4.0	4.1	3.9	4.0	2.2	2.4	2.3	2.3
85	3.8	3.6	3.7	3.7	2.2	2.0	2.4	2.2
86	3.7	3.6	3.8	3.7	2.4	2.2	2.3	2.3
87	3.7	3.7	3.7	3.7	2.1	2.4	2.4	2.3
88	3.5	3.8	3.8	3.7	2.3	2.6	2.3	2.4
89	3.9	4.0	4.1	4.0	2.5	2.7	2.3	2.5
90	3.9	3.7	3.8	3.8	2.4	2.5	2.3	2.4
91	3.6	3.8	3.7	3.7	2.6	2.3	2.3	2.4
92	3.5	3.7	3.6	3.6	2.2	2.1	2.3	2.2
93	3.9	3.8	3.7	3.8	2.6	2.7	2.5	2.6
94	4.0	3.9	3.8	3.9	2.1	2.0	2,5	2.2
95	3.6	3.5	4.0	3.7	2.4	2.6	2.5	2.4
96	4.0	3.8	3.9	3.9	2.4	2.5	2.6	2.4
97	4.0	3.7	3.7	3.8	2.2	2.2	2.5	2.3
98	3.7	3.9	3.8	3.8	2.3	2.5	2.1	2.3
99	3.9	3.7	3.8	3.8	2.4	2.5	2.0	2.3
100	3.9	3.9	3.9	3.9	2.4	2.4	2.4	2.4
101	4.0	3.9	3.8	3.7	2.2	2.6	2.1	2.3
102	3.6	3.6	3.9	3.7	2.5	2.5	2.5	2.5
103	3.8	3.7	3.6	3.7	2.2	2.7	2.6	2.5
104	3.8	3.8	3.8	3.8	2.1	2.4	2.1	2.2
105	3.6	4.0	3.8	3.8	2.5	2.3	2.4	2.4
106	3.7	3.8	3.6	3.7	2.3	2.7	2.2	2.4
107	4.0	3.8	3.9	3.9	2.3	2.1	2.5	2.3
108	4.1	3.8	3.8	3.9	2.3	2.5	2.4	2.4

Table XII: Ends per inch.

Experiment No.	1	2	3	4	5	Average
Gray	98	98	98	98	98	98.0
Desized	102	103	103	102	102	102.4
Scoured	103	103	104	103	103	103.2
1	107	107	108	107	107	107.2
2	106	107	107	108	107	107.0
3	108	107	107	108	106	107.2
4	107	108	106	108	107	107.4
5	108	107	106	108	107	107.2
6	107	106	107	108	108	107.2
7	107	107	107	107	107	107.0
8	107	106	108	106	107	106.8
9	108	107	107	107	106	107.0
10	107	106	107	107	107	106.8
11	107	107	108	107	107	107.2
12	108	107	107	108	107	107.4
13	107	107	107	108	107	107.2
14	106	107	107	107	108	107.0
15	107	107	108	106	107	107.0
16	107	108	108	106	106	107.0
17	108	107	107	107	107	107.2
18	107	107	107	108	107	107.2
19	107	107	106	107	109	107.2
20	106	107	107	108	106	106.8
21	107	107	106	108	107	107.0
22	109	107	107	107	106	107.2
23	106	107	107	108	107	107.0
24	107	108	107	108	107	107.4
25	106	106	108	108	109	107.2
26	107	107	107	107	107	107.0
27	107	107	108	107	108	107.2
28	108	106	106	106	109	107.0
29	107	108	107	107	107	107.2
30	107	107	107	108	106	107.0
31	107	108	107	106	108	107.2
32	107	107	107	107	108	107.2
33	108	106	107	108	106	107.0
34	106	107	108	107	108	107.2
35	107	107	105	107	107	107.0
36	107	107	107	107	108	107.2

Cont.

Table XII: Continued

Experiment No.	1	2	3	4	5	Average
37	108	106	107	108	107	107.2
38	107	107	106	107	108	107.0
39	108	107	107	107	107	107.2
40	107	107	108	107	107	107.2
41	107	108	107	108	107	107.4
42	107	107	108	107	107	107.2
43	108	107	107	107	108	107.4
44	107	108	107	106	107	107.0
45	107	107	107	107	108	107.2
46	108	107	107	107	107	107.2
47	107	107	108	107	107	107.2
48	107	107	107	107	108	107.2
49	106	107	107	108	107	107.0
50	107	107	107	107	107	107.0
51	107	106	107	107	107	106.8
52	107	107	108	107	106	107.0
53	107	106	107	107	108	107.0
54	107	107	108	107	107	107.2
55	106	108	108	107	107	107.2
56	107	107	108	107	107	107.2
57	108	108	107	107	107	107.4
58	108	106	107	107	107	107.0
59	107	107	107	108	107	107.2
60	108	108	107	107	107	107.4
61	107	107	107	107	108	107.2
62	107	106	108	107	107	107.0
63	108	107	107	107	106	107.0
64	107	107	106	108	107	107.0
65	108	107	107	106	107	107.0
66	106	108	107	107	107	107.0
67	107	107	107	108	107	107.2
68	108	107	107	106	107	107.0
69	107	107	108	107	107	107.2
70	107	108	106	107	107	107.0
71	107	107	107	107	108	107.2
72	107	108	107	108	107	107.4

Cont.

Table XII: Continued

Experiment No.	1	2	3	4	5	Average
73	107	107	108	107	106	107.0
74	108	106	107	107	108	107.2
75	107	107	108	107	107	107.2
76	108	106	107	106	108	107.0
77	107	107	107	108	107	107.2
78	107	108	107	107	107	107.2
79	107	107	107	106	108	107.0
80	106	108	107	108	106	107.0
81	107	107	107	108	107	107.2
82	108	107	107	107	107	107.2
83	106	108	107	108	106	107.0
84	108	107	108	107	107	107.4
85	108	107	106	107	107	107.0
86	107	107	107	108	106	107.0
87	107	108	107	106	107	107.0
88	107	107	107	107	107	107.0
89	107	108	107	108	107	107.4
90	107	107	108	107	107	107.2
91	107	106	107	107	108	107.0
92	107	107	106	107	107	106.8
93	108	107	107	107	107	107.2
94	107	107	108	107	107	107.2
95	107	106	107	108	107	107.0
96	108	107	107	107	107	107.2
97	107	107	108	107	107	107.2
98	107	107	107	107	108	107.2
99	107	108	107	107	107	107.2
100	107	107	107	108	107	107.2
101	106	107	107	108	107	107.0
102	107	108	106	107	107	107.0
103	107	107	107	107	107	107.0
104	108	107	106	108	107	107.2
105	107	108	107	107	107	107.2
106	106	107	107	108	107	107.0
107	107	108	107	107	107	107.2
108	106	108	106	108	108	107.2

Table XIII: Picks per Inch.

Experiment No.	1	2	3	4	5	Average
Gray	55	56	55	55	57	55.0
Desized	60	61	61	62	61	61.0
Scoured	62	63	62	61	62	62.0
1	63	63	64	65	62	63.4
2	64	63	63	64	63	63.4
3	63	64	63	64	63	63.4
4	63	63	64	63	64	63.4
5	64	63	63	63	63	63.2
6	63	63	63	64	64	63.4
7	63	65	63	63	64	63.6
8	65	64	63	63	63	63.6
9	63	63	64	63	64	63.4
10	65	63	63	63	63	63.4
11	64	64	64	63	63	63.6
12	63	64	63	63	64	63.4
13	64	63	64	63	63	63.4
14	63	63	64	63	64	63.4
15	63	65	63	63	63	63.4
16	63	64	63	63	64	63.4
17	63	63	63	63	65	63.4
18	63	65	64	63	63	63.6
19	64	63	64	63	63	63.4
20	64	63	63	64	64	63.4
21	63	63	64	63	63	63.4
22	64	64	63	63	63	63.4
23	63	63	65	63	63	63.4
24	64	63	64	63	63	63.4
25	63	64	64	63	63	63.4
26	64	63	63	63	64	63.4
27	63	63	65	64	63	63.4
28	63	64	63	63	63	63.4
29	64	63	64	64	63	63.4
30	63	63	63	63	64	63.4
31	63	63	64	63	64	63.4
32	64	63	63	63	63	63.2
33	64	64	63	63	63	63.4
34	64	63	64	63	63	63.4
35	63	64	63	64	63	63.4
36	63	63	65	63	63	63.4

Cont.

Table XIII: Continued

Experiment No.	1	2	3	4	5	Average
37	63	63	64	64	63	63.4
38	64	63	63	64	63	63.4
39	63	63	63	65	63	63.4
40	64	63	63	63	63	63.2
41	63	64	63	64	63	63.4
42	64	64	63	63	64	63.6
43	63	63	64	63	64	63.4
44	63	63	64	63	64	63.2
45	63	65	63	63	63	63.4
46	63	63	64	64	63	63.4
47	63	64	63	64	63	63.4
48	64	63	64	63	63	63.4
49	63	63	63	65	63	63.4
50	63	64	63	63	64	63.4
51	63	63	64	64	63	63.4
52	64	63	63	63	63	63.2
53	64	63	63	63	63	63.2
54	63	63	64	64	63	63.4
55	64	63	63	64	63	63.4
56	63	64	62	65	63	63.4
57	63	64	63	64	63	63.4
58	63	63	63	64	64	63.4
59	65	63	63	63	63	63.4
60	64	63	65	63	63	63.6
61	64	64	63	63	63	63.4
62	63	63	64	64	63	63.4
63	64	64	63	63	63	63.4
64	63	63	63	63	64	63.2
65	63	64	63	63	64	63.4
66	64	63	63	63	64	63.4
67	63	64	63	64	63	63.4
68	63	63	64	63	63	63.2
69	63	64	63	63	64	63.4
70	63	63	64	64	63	63.4
71	65	63	63	63	63	63.4
72	65	63	64	63	63	63.6

Cont.

Table XIII: Continued

Experiment No.	1	2	3	4	5	Average
73	63	64	64	63	63	63.4
74	64	63	63	64	63	63.4
75	64	63	64	63	63	63.4
76	64	63	63	63	64	63.4
77	63	64	63	64	63	63.4
78	63	64	63	63	63	63.2
79	65	64	63	63	63	63.6
80	63	63	64	63	64	63.4
81	64	63	63	64	63	63.4
82	65	63	63	63	63	63.4
83	63	64	63	65	63	63.6
84	64	63	63	64	63	63.4
85	63	63	64	63	63	63.2
86	63	64	63	64	63	63.4
87	63	63	64	63	64	63.4
88	64	64	63	63	63	63.4
89	63	65	63	64	63	63.6
90	63	63	64	63	64	63.4
91	64	64	63	63	63	63.4
92	63	64	63	63	63	63.2
93	63	64	65	63	63	63.6
94	63	63	63	64	63	63.2
95	63	64	63	63	64	63.4
96	64	64	63	63	63	63.4
97	63	63	63	64	64	63.4
98	63	63	64	64	63	63.4
99	63	64	63	64	63	63.4
100	63	63	64	63	64	63.4
101	64	64	63	63	63	63.4
102	63	63	63	64	65	63.6
103	63	65	64	63	63	63.6
104	63	63	63	64	63	63.2
105	64	64	63	63	63	63.4
106	63	63	63	64	64	63.4
107	63	64	64	63	63	63.4
108	63	64	63	64	63	63.4

Table XIV: Measurement of Light Reflection with the Photovolt Reflection Meter Model 610. Standard Used is Magnesium Carbonate 100%. Suppressed Zero. Readings with Red Filter. (White Opacity.)

Experiment	Reading	Experiment	Reading	Experiment	Reading
Gray	55.0				
Scoured	63.0				
1	73.0	37	74.0	73	75.0
2	74.0	38	74.5	74	75.5
3	75.0	39	75.0	75	76.0
4	76.0	40	76.0	76	77.0
5	76.0	41	76.5	77	77.5
6	76.5	42	77.0	78	77.5
7	75.0	43	75.5	79	76.0
8	76.0	44	76.5	80	77.0
9	76.5	45	77.0	81	77.0
10	77.0	46	77.5	82	77.5
11	77.5	47	78.0	83	78.0
12	77.5	48	78.5	84	78.5
13	75.0	49	76.0	85	77.0
14	75.5	50	76.5	86	77.5
15	76.0	51	77.0	87	77.5
16	77.0	52	77.5	88	78.5
17	77.5	53	78.0	89	79.0
18	78.0	54	78.0	90	79.5
19	76.0	55	76.0	91	77.5
20	77.0	56	77.0	92	78.0
21	78.0	57	78.0	93	78.0
22	78.5	58	79.0	94	79.0
23	79.0	59	79.5	95	80.0
24	79.5	60	80.0	96	80.5
25	77.0	61	77.0	97	77.5
26	77.5	62	77.5	98	78.0
27	78.0	63	78.0	99	78.5
28	78.5	64	79.0	100	80.0
29	79.0	65	80.0	101	80.5
30	80.0	66	80.5	102	80.5
31	77.5	65	78.0	103	78.5
32	78.0	68	78.0	104	78.0
33	78.5	69	79.0	105	79.0
34	79.0	70	80.0	106	79.5
35	80.0	71	80.0	107	79.5
36	79.0	72	79.5	108	80.5

Table XV: Measurement of Light Reflection with the Photovolt Reflection Meter Model 610. Standard Used Is Magnesium Carbonate 100%. Readings with Red Filter. (White Shine.)

Experiment	Reading	Experiment	Reading	Experiment	Reading
Gray	78.0				
Scoured	81.0				
1	86.0	37	88.0	73	88.0
2	87.0	38	88.5	74	89.0
3	87.5	39	89.0	75	89.5
4	87.5	40	89.0	76	90.0
5	88.0	41	89.5	77	90.5
6	88.0	42	90.0	78	91.0
7	87.0	43	88.5	79	89.0
8	87.5	44	89.0	80	89.5
9	87.5	45	89.5	81	90.0
10	88.0	46	89.5	82	90.5
11	88.5	47	90.0	83	89.5
12	88.5	48	90.5	84	90.0
13	87.0	49	88.5	85	90.0
14	87.5	50	89.0	86	91.0
15	88.0	51	89.5	87	91.0
16	88.5	52	90.0	88	91.5
17	89.0	53	90.5	89	91.5
18	89.0	54	91.0	90	92.0
19	88.0	55	89.0	91	88.0
20	88.5	56	89.5	92	89.0
21	89.0	57	89.5	93	90.0
22	89.5	58	90.0	94	90.5
23	90.0	59	90.5	95	91.0
24	90.0	60	91.0	96	91.0
25	87.5	61	89.0	97	89.0
26	88.0	62	89.5	98	90.0
27	88.5	63	90.0	99	90.0
28	89.0	64	89.5	100	90.5
29	89.5	65	90.5	101	91.0
30	90.0	66	90.5	102	91.5
31	88.5	67	89.0	103	90.0
32	89.0	68	89.5	104	90.0
33	89.5	69	90.0	105	90.5
34	89.5	70	90.0	106	90.5
35	90.0	71	90.5	107	91.0
36	90.0	72	90.0	108	91.0

Table XVI: Raveled-Strip Test for Tensile Strength in Fabric Material. Warp Breaks in Pounds. Break Given as Percentage of Corrected Tensile Strength of Desized Sample as to Shrinkage and Loss in Weight.

Experiment No.	1	2	3	4	5	Average	Percentage of Corrected Desized Break of 123.3 lbs
Gray Fabric	130	131	128	129	131	129.8	
Desized	122	118	123	124	124	122.2	
Scoured	125	129	124	123	125	125.2	
1	118	128	123	126	127	124.4	100.9
2	127	119	124	126	123	123.8	100.4
3	122	125	123	117	119	121.2	98.3
4	130	122	107	121	118	119.6	97.0
5	113	114	122	115	125	117.8	95.5
6	123	114	110	116	121	116.8	94.7
7	128	130	122	123	118	124.2	100.7
8	118	128	120	122	120	121.6	98.6
9	116	124	120	114	120	118.8	96.4
10	114	116	124	114	115	116.6	94.6
11	118	117	119	115	112	116.2	94.2
12	110	115	112	117	118	114.4	92.8
13	128	124	119	124	121	123.2	99.9
14	121	119	124	120	120	120.8	98.0
15	127	120	119	110	113	117.8	95.5
16	120	118	121	113	110	116.4	94.4
17	111	120	110	118	113	114.4	92.8
18	119	111	113	117	110	114.0	92.5
19	125	120	121	122	112	120.0	97.3
20	114	118	122	119	113	117.2	95.0
21	111	115	118	116	117	115.4	93.6
22	117	112	115	111	113	113.6	92.1
23	108	109	117	114	108	111.2	89.4
24	110	102	109	116	110	109.4	88.7
25	123	117	115	118	120	118.6	96.2
26	115	118	117	114	118	116.4	94.4
27	113	115	113	118	112	114.2	92.6
28	111	113	109	112	117	112.4	91.2
29	110	114	112	105	111	110.4	89.5
30	109	105	108	114	103	107.8	87.4
31	118	116	119	112	119	116.8	94.7
32	111	107	116	118	115	113.4	92.0
33	108	112	109	115	107	110.2	89.4
34	112	105	108	105	107	107.4	87.1
35	106	109	103	107	98	104.6	84.8
36	96	106	108	99	97	101.2	82.1

Cont.

Table XVI: Continued

Experiment No.	1	2	3	4	5	Average	Percentage of Corrected Desized Break of 123.3 lbs
37	116	113	111	109	117	113.2	91.8
38	113	115	108	109	107	110.4	89.5
39	111	106	105	101	108	106.2	86.1
40	100	106	98	102	106	102.4	83.0
41	99	97	95	102	105	99.6	80.8
42	97	98	101	94	92	96.4	78.2
43	109	112	115	111	114	112.2	91.0
44	112	114	108	111	103	109.6	88.9
45	109	104	105	101	108	105.4	85.5
46	100	99	103	101	98	100.2	81.3
47	97	103	95	94	98	97.4	79.0
48	98	91	97	96	94	95.2	77.2
49	112	114	108	110	108	110.4	89.5
50	102	107	109	101	109	105.6	85.6
51	104	99	106	100	98	101.4	82.2
52	94	99	105	102	96	99.2	80.5
53	100	98	94	92	101	97.0	78.7
54	94	91	98	92	98	94.6	76.7
55	100	104	109	102	106	104.2	84.5
56	102	98	99	101	102	100.4	81.4
57	100	97	96	98	95	97.2	78.8
58	94	95	89	98	95	94.2	76.4
59	85	89	94	98	91	91.4	74.1
60	83	96	84	94	89	89.2	72.3
61	103	101	101	97	106	101.6	82.4
62	99	95	99	92	101	97.2	78.8
63	97	100	86	93	91	93.4	75.8
64	83	88	94	91	90	89.2	72.3
65	83	82	88	90	89	86.4	70.1
66	86	79	88	85	83	84.2	68.3
67	100	104	97	98	99	99.6	80.8
68	91	98	97	94	96	95.2	77.2
69	90	89	97	91	92	91.8	74.5
70	85	89	93	87	89	88.6	71.9
71	82	88	85	86	85	85.2	69.1
72	81	95	84	79	88	83.4	67.6

Cont.

Table XVI: Continued

Experiment No.	1	2	3	4	5	Average	Percentage of Corrected Desized Break of 123.3 lbs
73	106	108	99	96	102	102.2	82.9
74	100	104	98	101	99	100.4	81.4
75	95	97	99	92	103	97.2	78.8
76	97	94	91	96	94	94.4	76.6
77	87	91	92	90	90	90.0	73.0
78	87	85	88	87	89	87.2	70.7
79	98	97	102	97	103	99.4	80.6
80	97	96	91	99	95	95.6	77.5
81	89	91	87	84	90	88.2	71.5
82	85	81	89	85	87	85.4	69.3
83	86	79	81	84	83	82.6	67.0
84	75	86	79	75	81	79.2	64.2
85	98	99	98	96	90	96.2	78.0
86	90	89	93	91	90	90.6	73.5
87	88	87	81	80	86	84.4	68.5
88	80	79	84	82	85	82.0	66.5
89	76	80	82	79	84	80.2	65.0
90	74	79	82	78	79	78.4	63.6
91	97	93	92	97	94	94.6	76.7
92	90	87	89	92	88	89.2	72.3
93	82	86	81	88	86	84.6	68.6
94	79	84	76	82	80	80.2	63.0
95	76	72	80	85	70	76.6	62.1
96	70	73	79	71	69	72.4	58.7
97	90	91	94	92	95	92.4	74.9
98	89	87	83	92	87	87.6	71.0
99	86	80	83	81	82	82.4	66.8
100	80	75	81	78	80	78.8	63.9
101	70	75	72	74	76	73.4	59.5
102	70	65	72	66	68	68.2	55.3
103	95	90	88	92	89	90.8	73.6
104	87	86	89	80	85	85.4	69.3
105	80	84	82	79	82	81.4	66.0
106	79	75	76	78	80	77.6	62.9
107	75	79	71	72	74	74.2	60.2
108	67	66	74	72	68	69.4	56.3

Table XVII: Raveled-Strip Test for Tensile Strength on Fabric Material. Filling Breaks in Pounds. Break Given as Percentage of Corrected Tensile Strength of Desized Sample As To Shrinkage and Loss in Weight.

Experiment No.	1	2	3	4	5	Average	Percentage of Corrected Desized Break of 107.6 lbs.
Gray	90	91	89	88	91	89.8	
Desized	101	98	102	105	101	101.4	
Scoured	107	110	109	108	108	108.4	
1	104	99	101	98	99	100.2	93.1
2	101	95	99	97	100	98.4	91.4
3	98	99	93	93	95	95.6	88.8
4	90	93	94	92	93	92.4	85.9
5	89	90	91	90	91	90.2	83.8
6	90	89	86	88	89	88.4	82.2
7	99	98	103	95	98	98.6	91.6
8	98	95	92	94	97	95.2	88.5
9	92	94	92	99	90	93.4	86.8
10	87	94	91	89	90	90.2	83.8
11	85	87	89	90	85	87.2	81.0
12	85	89	88	82	84	85.6	79.6
13	100	107	93	101	98	99.8	92.8
14	98	97	93	91	102	96.2	89.4
15	91	96	89	93	98	93.4	86.8
16	84	93	90	96	87	90.0	83.6
17	88	82	85	89	90	86.8	80.7
18	88	84	82	87	81	84.4	78.4
19	100	97	93	104	98	98.4	91.4
20	90	98	94	97	96	95.0	88.3
21	93	90	96	94	93	93.2	86.6
22	90	94	89	88	93	90.8	84.4
23	88	84	85	92	87	87.2	81.0
24	88	83	90	86	81	85.6	79.6
25	97	98	90	92	97	94.8	88.1
26	89	92	95	87	90	90.6	84.2
27	87	83	87	85	90	86.4	80.3
28	80	89	78	84	82	82.6	76.8
29	80	78	81	80	82	80.2	74.5
30	80	75	83	76	80	78.4	72.9
31	91	95	87	91	94	91.8	85.3
32	89	90	90	91	83	88.6	82.3
33	87	85	82	89	84	85.4	79.4
34	83	87	81	81	80	82.4	76.6
35	80	84	78	77	81	80.0	74.3
36	80	76	73	80	77	77.2	71.7

Cont.

Table XVII: Continued

Experiment No.	1	2	3	4	5	Average	Percentage of Corrected Desized Break of 107.6 lbs.
37	92	93	89	90	93	91.4	84.9
38	88	84	93	88	85	87.6	81.4
39	86	84	86	89	82	85.4	79.4
40	81	86	80	82	87	83.2	77.3
41	78	85	79	77	82	80.2	74.5
42	80	76	75	79	78	78.4	72.9
43	90	93	88	89	91	90.2	83.8
44	87	86	81	86	89	85.8	79.7
45	83	82	80	79	82	81.2	75.5
46	78	74	80	80	75	77.4	71.9
47	75	78	75	73	75	75.2	69.9
48	70	73	74	70	71	71.6	66.5
49	89	70	88	90	86	88.6	82.3
50	85	81	85	89	79	83.8	77.9
51	80	83	78	83	77	80.2	74.5
52	79	78	78	80	72	77.4	71.9
53	73	70	74	76	78	74.2	69.0
54	69	73	75	63	71	70.2	65.2
55	84	89	84	85	90	86.4	80.3
56	84	82	79	80	86	82.2	76.4
57	76	75	80	74	79	76.8	71.4
58	72	70	73	70	78	72.6	67.5
59	65	70	74	69	70	69.6	64.7
60	68	65	69	72	68	68.4	63.6
61	86	85	83	88	80	84.4	78.4
62	80	78	80	79	87	80.8	75.1
63	76	79	74	77	75	76.2	70.8
64	74	77	71	73	76	74.2	69.0
65	70	73	68	70	74	71.0	66.0
66	67	65	71	68	70	68.2	63.4
67	80	84	83	77	81	81.0	75.3
68	79	75	77	80	83	78.8	73.2
69	78	74	75	73	76	75.2	69.9
70	72	70	74	72	71	71.8	66.7
71	70	67	66	71	67	68.2	63.4
72	68	66	65	69	64	66.4	61.7

Cont.

Table XVII: Continued

Experiment No.	1	2	3	4	5	Average	Percentage of Corrected Desized Break of 107.6 lbs
73	86	85	86	85	84	85.2	79.2
74	84	86	84	81	82	83.4	77.5
75	79	80	77	81	79	79.2	73.6
76	78	74	78	77	80	77.4	71.9
77	73	74	75	74	77	74.6	69.3
78	73	70	69	72	75	71.8	66.7
79	84	87	83	84	81	83.8	77.9
80	87	79	77	80	80	80.6	75.0
81	77	74	80	76	79	77.2	71.7
82	73	75	76	78	71	74.6	69.3
83	70	69	72	78	67	71.2	66.2
84	69	65	68	71	71	68.8	63.9
85	85	79	83	81	85	82.6	76.8
86	80	81	77	84	79	80.2	74.5
87	80	78	76	79	74	77.4	71.9
88	76	71	75	74	75	74.2	69.0
89	75	69	71	73	75	72.6	67.5
90	66	76	70	68	69	70.2	65.2
91	87	83	84	85	83	84.4	78.4
92	84	81	78	80	83	81.2	75.5
93	79	75	81	82	76	78.6	73.0
94	76	78	76	76	71	75.4	70.1
95	79	71	70	73	69	73.4	68.2
96	69	64	67	66	70	67.2	62.5
97	83	81	76	80	81	80.2	74.5
98	78	74	71	80	75	75.6	70.3
99	76	70	74	71	73	72.8	67.7
100	67	69	66	69	70	68.2	63.4
101	64	66	65	62	65	64.4	59.8
102	64	69	63	61	62	63.5	59.3
103	78	80	77	78	73	77.2	71.7
104	75	78	70	76	72	74.2	69.0
105	67	65	72	69	70	68.6	63.8
106	71	63	69	62	66	66.2	61.5
107	67	64	70	61	61	64.6	60.0
108	64	69	61	58	62	62.8	58.4

Table XVIII: Absorbency Test on Fabric Material in Seconds per Sample.

Experiment No.	1	2	3	4	5	Average
Gray	1800+	1800+	1800+	1800+	1800+	1800+
Desized	380	310	340	360	350	350
Scoured	4.7	4.9	4.3	4.4	4.6	4.58
1	4.2	4.3	4.0	3.9	4.3	3.34
2	3.9	3.8	3.4	4.4	3.1	3.72
3	2.8	3.8	3.6	3.2	3.6	2.34
4	2.2	2.8	3.8	3.6	2.1	2.90
5	3.9	3.6	3.2	3.2	3.4	3.46
6	3.3	3.1	3.1	3.2	3.4	3.22
7	3.8	3.6	4.1	3.6	3.3	3.94
8	3.6	4.2	3.0	3.4	3.3	3.50
9	2.3	4.1	4.1	3.2	3.1	3.36
10	4.0	3.5	2.9	3.1	3.4	3.38
11	4.2	4.0	3.2	2.6	3.2	3.44
12	3.4	3.6	3.0	3.2	3.2	3.28
13	4.2	4.3	3.9	4.1	3.7	4.04
14	3.6	4.0	3.9	3.8	3.9	3.84
15	3.8	4.2	4.0	3.6	3.4	3.80
16	3.0	3.8	3.6	3.4	3.2	3.40
17	3.6	4.0	3.8	3.4	3.3	3.62
18	3.5	3.1	3.3	3.0	3.2	3.22
19	3.8	3.6	3.4	4.0	3.9	3.74
20	3.0	3.1	3.8	2.6	2.9	3.08
21	3.2	2.0	2.8	3.3	3.6	2.98
22	2.8	2.6	2.5	3.1	3.1	2.82
23	2.6	2.8	2.4	3.1	3.0	2.78
24	3.1	2.2	2.6	3.2	2.3	2.68
25	3.3	3.4	4.0	3.6	3.5	3.56
26	2.4	2.8	2.6	2.9	3.2	2.78
27	2.6	3.2	2.9	3.1	2.7	2.90
28	3.1	2.5	2.4	3.3	2.9	2.84
29	2.6	2.3	3.0	2.7	2.8	2.68
30	3.0	2.7	2.6	2.9	2.2	2.68
31	3.0	3.1	3.2	3.1	3.4	3.16
32	2.8	2.7	2.9	2.6	2.9	2.78
33	2.9	2.6	3.0	2.7	3.0	2.84
34	2.8	3.0	2.4	3.0	2.5	2.74
35	2.7	3.2	2.1	2.6	2.3	2.59
36	2.5	3.0	2.7	2.4	2.5	2.62

Cont.

Table XVIII: Continued

Experiment No.	1	2	3	4	5	Average
37	2.9	3.2	3.4	2.9	3.2	3.12
38	3.0	2.7	2.8	2.2	2.8	2.70
39	2.3	2.6	2.7	2.4	2.2	2.44
40	2.2	2.7	2.1	2.3	2.5	2.36
41	1.9	1.8	2.1	2.2	1.9	1.98
42	2.0	1.9	1.8	2.1	2.0	1.96
43	2.0	2.1	2.6	2.7	2.2	2.32
44	1.8	1.6	2.0	1.9	1.8	1.82
45	2.2	1.8	1.9	2.0	2.3	2.04
46	2.1	2.0	2.0	2.0	1.8	1.98
47	1.5	2.0	1.8	1.7	1.4	1.68
48	2.0	1.4	1.7	1.8	1.5	1.68
49	2.6	2.3	2.4	2.5	2.7	2.50
50	1.6	2.0	2.0	1.8	1.7	1.82
51	1.7	1.6	2.2	2.0	1.9	1.88
52	1.5	1.6	1.8	1.7	1.6	1.64
53	1.7	1.8	2.0	1.8	1.9	1.84
54	1.8	1.6	1.7	2.0	1.7	1.76
55	2.1	2.2	2.6	2.4	2.2	2.30
56	2.0	2.0	2.1	2.3	2.2	2.12
57	2.0	2.0	2.0	2.2	1.8	2.00
58	1.9	1.8	2.1	1.8	1.7	1.86
59	1.7	1.8	1.6	1.9	1.8	1.76
60	1.6	1.8	1.7	1.7	1.5	1.66
61	2.4	2.6	2.5	2.4	2.3	2.44
62	2.6	2.4	2.0	2.2	2.6	2.36
63	2.5	2.2	2.1	2.3	2.2	2.26
64	2.0	2.1	2.2	2.6	2.5	2.28
65	2.3	2.2	2.5	2.3	2.6	2.38
66	2.0	1.8	1.5	1.9	1.8	1.80
67	2.5	2.8	2.9	3.0	2.7	2.78
68	2.4	2.6	2.2	2.6	2.4	2.44
69	2.2	2.4	2.0	1.9	2.2	2.14
70	1.7	1.6	1.9	2.0	2.1	1.86
71	1.5	1.9	1.8	1.7	1.9	1.76
72	1.4	1.8	1.9	1.7	1.8	1.72

Cont.

Table XVIII: Continued

Experiment No.	1	2	3	4	5	Average
73	2.3	2.4	2.2	2.6	2.8	2.46
74	2.1	2.5	2.2	2.3	2.2	2.26
75	2.0	1.9	1.6	1.8	1.5	1.76
76	1.4	1.6	1.5	1.4	1.8	1.54
77	1.3	1.5	1.2	1.4	1.6	1.40
78	1.2	1.0	1.4	1.2	1.3	1.22
79	2.0	2.1	2.2	2.4	2.0	2.14
80	2.0	1.8	1.9	1.7	1.8	1.84
81	1.6	1.7	1.7	1.9	1.6	1.70
82	1.3	1.2	1.4	1.5	1.4	1.36
83	1.1	1.3	1.4	1.2	1.1	1.28
84	1.9	1.7	1.8	1.8	1.9	1.82
85	1.6	1.4	1.5	1.6	1.5	1.52
86	1.3	1.2	1.6	1.4	1.5	1.40
87	1.2	1.1	1.0	1.1	0.9	1.06
88	1.0	0.9	1.1	1.2	1.0	1.04
89	1.0	0.8	1.2	1.0	0.9	0.98
90	0.8	1.0	0.9	1.1	1.0	0.96
91	1.8	1.9	1.7	1.9	1.8	1.82
92	1.6	1.4	1.7	1.4	1.5	1.52
93	1.5	1.3	1.4	1.8	1.3	1.46
94	1.3	1.2	1.8	1.2	1.5	1.40
95	1.5	1.2	1.6	1.4	1.3	1.40
96	1.0	1.2	1.1	1.0	0.9	1.04
97	1.4	1.6	1.8	1.7	1.5	1.60
98	1.5	1.6	1.4	1.6	1.5	1.52
99	1.2	1.2	1.4	1.2	1.3	1.26
100	1.0	1.1	1.3	1.0	1.2	1.12
101	1.0	0.9	0.8	0.9	1.1	0.94
102	0.9	0.8	1.0	1.0	0.8	0.90
103	1.4	1.6	1.5	1.6	1.3	1.48
104	1.2	1.3	1.5	1.4	1.2	1.32
105	1.0	1.2	1.1	1.0	1.2	1.10
106	1.0	0.9	1.0	0.9	0.9	0.94
107	0.9	0.8	0.6	0.8	0.9	0.80
108	1.0	0.8	1.0	1.0	0.6	0.88

SECTION IV

ANALYSIS OF RESULTS AND CONCLUSIONS

ANALYSIS OF RESULTS AND CONCLUSIONS

Upon completion of the preceding experimental work, the following conclusions have been reached.

1. The pH of sodium hypochlorite bleaching solutions drops rapidly in the first forty-five minutes of treatment in presence of cotton, decreasing toward the end of longer periods of time.

2. At temperatures higher than 76 degrees Fahrenheit, the drop in pH increases in proportion to the increase in temperature.

3. The concentration of the bleaching solution will affect the drop in pH in direct proportion to the increase in concentration.

4. The amount of chlorine consumed in bleaching is directly proportional to the temperature and concentration of the sodium hypochlorite solution. An increase in the length of time of treatment brings about a decrease in the ratio of chlorine consumption, which is great during the first forty-five minutes of treatment and decreases proportionally with longer periods of time.

5. The weight of the fabric lost in chemicking is proportional to the concentration, temperature and time of treatment of the hypochlorite solution.

6. The shrinkage of cotton fabrics is entirely

independent of any conditions in chemicking.

7. The construction of cotton fabrics changes with shrinkage, but this change is also independent of the bleaching conditions used.

8. The white opacity of cotton fabrics is increased as the concentration, temperature and time of treatment are increased. The improvement in white opacity is rapid at first and diminishes as the conditions are increased.

9. The white shine of cotton fabrics also increases with an increase in the conditions of treatment. An increase in temperature and time will cause a rapid increase in the amount of white shine obtained at first and then the results will tend to level off. An increase in concentration will cause a rapid increase in white shine which will level off with concentration up to four grams of available chlorine per liter. At this point, an increase in concentration will also cause a rapid increase in white shine of the cotton.

10. A one hundred percent whiteness reading was not obtained with any treatment used.

11. The tensile strength of the cotton fabric decreases in proportion to the increase of temperature of chemicking.

12. T he tensile strength of the cotton fabric decreases in proportion to an increase in concentration and time of treatment.

13. The treatment of cotton fabrics with sodium hypochlorite solutions of any concentration from one to six grams of available chlorine per liter causes a decrease in tensile strength which is not due to the loss in weight since this factor is offset by the shrinkage of the fabric. The loss in tensile strength considered acceptable in this work is from 5 to 15 percent.

14. The absorbency of bleached cotton fabrics depends largely on the kier boiling operation. Chemicking will improve the absorbency of the bleached fabric. Absorbency increases with increases in temperature, concentration and time of treatment.

15. The whiteness of the cotton bleached is not proportional to the amount of chlorine consumed or to the percentage of tensile strength lost.

16. There is an indication of cellulose degradation in samples treated at 116 degrees Fahrenheit. At 96 degrees Fahrenheit cellulose degradation is almost certain with concentrations over four grams per liter of available chlorine, and treatments of over forty-five minutes. At 76 degrees Fahrenheit cellulose degradation may be present when the concentration used is above five grams of chlorine available per liter and for periods of over one hour. At this point it would be necessary to point out that no chemical test for cellulose degradation has been conducted and these conclusions are drawn on the basis of trends of loss in tensile

strength.

17. An increase of one gram of available chlorine per liter is equivalent to an increase of fifteen minutes of treatment at any temperature of treatment below 120 degrees Fahrenheit.

18. The best results obtained in this study were at 76 degrees Fahrenheit with a concentration of four grams of chlorine available per liter and for sixty minutes of treatment. These results were selected because they give the best all round bleached product.

SUGGESTIONS FOR FURTHER STUDY

During the performance of this study, several interesting and profitable problems for further study have been found. It is most unfortunate that the nature of this work and the time available have not permitted us to investigate these side problems. However, they are here stated and it is hoped that they may be helpful to some newcomer into the research field.

1. It would be interesting to know how the chlorine, liberated at different rates under different conditions in bleaching, is used up. How much chlorine is actually used in bleaching, how much gas will damage the fiber, and what amount is actually lost, if any.

2. Which is the cause of the loss in tensile strength of cotton fabrics during chemicking when no cellulose degradation has taken place. Is it correct to call such phenomenon a "loss in cellulose"?

3. Is there any relation between the absorbency of the bleached fabric and the amount of cellulose degradation present? If so, how ? Would it be possible to measure the amount of cellulose degraded by measuring the absorbency of the fabric?

4. Which is the exact point at which cellulose degradation begins and harmless bleaching ends. A chemical proof of the conclusions reached would be very useful.

BIBLIOGRAPHY

Books

Anon.; "American Association of Textile Chemists and Colorists", "1942 Year Book", Vol. XIX, Howes Publishing Co., Inc.,1942.

Anon.; "American Society for Testing Materials", "Standards on Textile Materials", Philadelphia, Pa., 1944.

Bean, Percy; "The Chemistry and Practice of Finishing", Hutton, Hartley & Co., Ltd., Manchester, 1926.

Bottler, Max; "Modern Bleaching Agents and Detergents", Scott, Greenwood & Son, London, 1910.

Bowman, F. H.; "The Structure of the Cotton Fiber", MacMillan and Co., Limited, London, 1908.

Britton, Hubert T. S.; "Hydrogen Ions", D. Van Nostrand Company, Inc., New York, 1929.

Brown, Harry Bates; "Cotton", McGraw-Hill Book Company, Inc., New York, 1927.

Haven, George B.; "Industrial Fabrics", Wellington Sears Company, New York, N. Y., 1941.

Heuser, Emil; "Textbook of Cellulose Chemistry", McGraw-Hill Book Company, Inc., New York, 1924.

Higgins, S. H.; "Bleaching", Longanms, Green & Co., London, 1921.

Higgins, S. H.; "A History of Bleaching", Longmans, Green and Co., New York, 1924.

Hubner, Julius; "Bleaching and Dyeing of Vegetable Fibrous Materials", Constable & Company, Ltd., London, 1927.

Johnson, W. H.; "Cotton and Its Production", MacMillan and Co., Limited, London, 1926.

Mahin, Edward G.; "Quantitative Analysis", McGraw-Hill Book Company, Inc., New York, 1932.

Matthews, J. Merritt; "Bleaching and Related Processes", The Chemical Catalog Company, Inc., New York, 1921.

Matthews, J. Merritt; "Application of Dyestuffs", John Wiley & Sons, Inc., New York, 1940.

McMyn, J. W.; and Bardsley, J. W.; "Bleaching, Dyeing, Printing and Finishing", Sir Isaac Pitman & Sons, Ltd., London, 1932.

Ott, Emil; "Cellulose and Cellulose Derivatives", Interscience Publishers, Inc., New York, N. Y. 1943.

Steven, Alec B.; "Textile Bleaching", Sir Isaac Pitman & Sons, Ltd., London, 1934.

Trotman, S. R.; "The Bleaching, Dyeing, and Chemical Technology of Textile Fibers", Charles Griffin & Company, Limited, London, 1925.

Trotman, S. R.; and Thorp, E. L.; "The Principles of Bleaching and Finishing Cotton", Charles Griffin & Company, Limited, London, 1927.

U. S. Department of Agriculture; "The Cotton Plant", Government Printing Office, Washington, 1896.

Wertheim, E.; "Textbook of Organic Chemistry", The Blakiston Company, Philadelphia, 1939.

Periodicals

Alling, M. W.; "Kier Boiling, Peroxide and Sodium Hypochlorite Bleaching, and Anti-chloring Cellulose Fabrics", American Dyestuff Reporter, XXII (1933), p.544-46, 558.

Anon.; "Chlorine in Bleaching", Textile Colorist, LII (1930), p.844.

Anon.; "History Repeats Itself in the Bleaching Industry", Textile Colorist, LIII (1931), p.123.

Anon.; "Ultraviolet, an Aid to Bleaching", Textile Colorist, LVIII (1936), p.463.

Anon.; "Bleaching Goods with Textone Activated with Hypochlorite", Textile Colorist, LXII (1941), p.491.

Anon.; "Some Notes on the Bleaching of Vegetable Fibers", Textile Colorist, LXIII (1941), p.398-400.

Bergmann, K. H.; "Oxycellulose", Journal of the Society of Dyers and Colorists, L (1934), p.61.

Blackwelder, C. D.; "The Treatment of Water for Bleaching and Dyeing", Textile Colorist, LII (1930), p. 769-70.

Blakeley, J. D., Preston, J. M. and Scholefield, F.; "Determination of Active Chlorine in Hypochlorite Liquors", Journal of the Society of Dyers and Colorists, XLVI (1930), p. 230-33.

B leacher; "The Bleaching of Textile Materials", Textile Colorist, LIX (1937), p. 522-24.

Bothamley, J.; "Kier Boiling", American Dyestuff Reporter, (1934), p. 350-51.

Butterworth, E.; "The Bleaching of Cellulose with Special Reference to Bast Fibers", Journal of the Society of Dyers and Colorists, LV (1939), p. 589-96.

Chapin, H. C.; "The Hydrogen Ion Concentration of Hypochlorite Bleaching Solution", American Dyestuff Reporter XXII (1933), p. 536-37.

Chem. Fab. von Heyden A. G.; "Powder Yielding Active Chlorine", Journal of the Society of Dyers and Colorists, XLVIII (1932), p.39.

Davidson, G. F.; "Hypochlorite Solutions", Journal of the Society of Dyers and Colorists, XLIX (1933), p. 266.

Davidson, G. F.; "The Modification of Cellulose by Oxidation", Journal of the Society of Dyers and Colorists, LVI (1940), p.58-67.

DuPont,; "Treatment of Textile Materials", Journal of the Society of Dyers and Colorists, LVII (1942), p. 131.

Elod, E. and Vogel, F.; "Bleaching Cotton with Chlorine", Journal of the Society of Dyers and Colorists, LIII (1937), p.115-16.

Ermen, W.F.A.; "An Improved Ferricyanide Reagent for the Detection of Oxycellulose", Journal of the Society of Dyers and Colorists, LI (1935), p.127-29.

Estey, A. C.; "Improvements Made in Bleaching", Textile Colorist, LIV (1932), p.455-56.

Fennell, F. L.; "The Significance and Utility of Cuprammonium Fluidity in Textile Bleaching", American Dyestuff Reporter, XXX (1941), p.481-86.

Goeble, E.F.; "Addition of Sodium Bicarbonate in Calcium Hypochlorite Bleaching Baths", Journal of the Society of Dyers and Colorists, LIV (1938), p.243.

Goldthwait, C.; "Hydrocellulose and Oxycellulose", American Dyestuff Reporter, XXVII (1938), p.692-94.

H. Tk. Bohme A.-G.: "Bleaching Vegetable Fibers", Journal of the Society of Dyers and Colorists, L (1934), p.63.

Hall, A.J.; "Comparison of a Modern U.S.S.R. Kiering and Bleaching Process with the Usual Western Methods", American Dyestuff Reporter, XXII (1933), p.1-4.

Hall, A.J.; "Bleaching Cotton Goods", American Dyestuff Reporter, XXV (1936), p.387-90.

Haller, R.; "Differentiation Between Hydrocellulose and Oxycellulose", Journal of the Society of Dyers and Colorists, XLVII (1931), p.211.

H ampson, C.G.; "The Chemistry of Cotton Bleaching", Textile Colorist, LX (1938, p.700-03.

Holmes, J. F.; "The Boiling and Bleaching on Cotton", Textile Colorist, LVI (1934), p.53-60.

Holmes, J.F.; "Oxycellulose", Textile Colorist, LVI (1934), p. 307-08.

Holt, T.W.; and Kilpatrick, A.S.; "Bleaching Fabrics", Journal of the Society of Dyers and Colorists, XLIX (1933), p.237.

Hughes, T.F.; "Bleaching Cotton Piece Goods in One Boil", American Dyestuff Reporter, XIX (1930), p.455-58

I. G. Farbenindustrie A.-G.; "Stable Bleaching Powder", Journal of the Society of Dyers and Colorists, XLVII (1931), p.267.

I. G. Farbenindustrie A.-G.; "Storage-proof Bleaching Powder", Journal of the Society of Dyers and Colorists, XLVII (1931), p.267.

I. G. Farbenindustrie A.-G. "Bleaching Powder", Journal of the Society of Dyers and Colorists, XLIX (1933) p. 332.

Imperial Chemical Industries, Ltd. and Carter, C.; "Bleaching Powder", Journal of the Society of Dyers and Colorists, XLVII (1931), p.174.

Ivey, J. W.; "The Use of Chlorine in Bleaching Cotton Goods", American Dyestuff Reporter, XIX (1930), p.611-16.

Jacquemain, R.P. and Doll, J.H.; "Influence of Time, Light and Temperature on the Storage of Eau de Javel", Journal of the Society of Dyers and Colorists, LII (1936), p.97.

Jambuserwala, G. B.; "Degree of Whiteness Obtainable by Bleaching", American Dyestuff Reporter, XXVI (1937) p.799-802, 820.

Johnson, G.H., Anderson, A.I., Parker, H.O. and MacMahon, J.D.; "The Influence of Bleaching on the Whiteness and Tensile Strength of Cotton Fabrics", American Dyestuff Reporter, XXIII (1934), p.519-20.

Kauffmann, H.; "Kinetics of Chlorine Bleaching", Journal of the Society of Dyers and Colorists, XLVI (1930), p.414.

Kauffmann, H.; "The Latest Research Work on Cotton Bleaching", American Dyestuff Reporter, XXI (1932), p.647-49.

Kenny, W. R.; and Reed, A.B.; "Simplified pH Control and Its Importance in the Processing of Textiles", Textile Colorist, LIV (1932), p.731-33, 780.

Kornreich, E.; "Bleaching Cellulose", Journal of the Society of Dyers and Colorists, LVI (1940), p.352-55.

MacMillan, R.B. and Taylor, M.C.; "Hypochlorite Compositions", Journal of the Society of Dyers and Colorists, XLVI (1930), p.352.

McCrumb, F.R.; "New Bleaching and Chlorine Control Equipment", Textile Colorist, LIII (1931), p.682.

Mecheels, O.; "The Bleaching Process", Journal of the Society of Dyers and Colorists, LI (1935), p.430.

Mullin, C.E.; "pH Control in Bleaching and Finishing Cotton", Textile Colorist, LV (1933), p.81-4, 132.

Perley, G.A.; "Modern Views of pH Measurements", American Dyestuff Reporter, XXVI (1937), p.832-36.

Pettinger, A.H.; "Recent Research and Developments in Bleaching Technique", Textile Colorist, LVII (1935), p. 317-19.

Pilot Laboratories, Inc.; "Bleaching Agents", Journal of the Society of Dyers and Colorists, XLVII (1931), p.83.

Rhodes, F.H. and Bascom, C.H.; "Effect of pH on the Detergent Action of Soap", Journal of the Society of Dyers and Colorists, XLVIII (1932), p.47.

Ridge, B. P. and Little, A.H.; "Control of pH in Bleaching", American Dyestuff Reporter, XXXI (1942), p.515-16, 536.

Ridge, B.P. and Little, A.H.; "Control of PH in Hypochlorite Solutions", Journal of the Society of Dyers and Colorists, LVIII (1942), p.175-76.

Rupp, R.E.; "Continuous Peroxide Bleaching", American Dyestuff Reporter, XXXI (1942), p.638-40.

Savell, W.L. and Ivey, J.W.; "Use and Misuse of Chlorine in Textile Bleaching", American Dyestuff Reporter, XX (1931), p.97-100.

Savell, W.L.; "Bleaching with Chlorine", American Dyestuff Reporter, XXIV (1935), p.189-92.

Scholefield, F. and Ward, D.; "Some Observations on Kier Boiling Efficiency", Journal of the Society of Dyers and Colorists, LI (1935), p.172-78.

Schwalbe, C.G. and Wenzel, H.; "Development of the Rapid or Concentrated Bleaching Process", Journal of the Society of Dyers and Colorists, LI (1935), p.430-31.

Sommer, H. and Markett, H.; "Detection of Oxy- and Hydrocelluloses", Journal of the Society of Dyers and Colorists, XLVII (1931), p.304.

Tagliani, G.; "Protection of Vegetable Fibers During Bleaching", Journal of the Society of Dyers and Colorists, LIV (1938), p.39-40.

Technicus,; "Notes on the Tendering of Cotton Piece Goods in Bleaching, Dyeing and Printing", Textile Colorist, LIX (1937), p.9-12.

Thomas, H.A.; "Oxycellulose and Hydrocellulose", American Dyestuff Reporter, XXII (1933), p.355-56, 371-77.

Ullmann, G.; "Bleaching Solutions of Chlorines and Their Self-production", Textile Colorist, LXV (1943), p.227, 231,253,273.

Utermohlen, H .; "Determination of the Hydrolytic Acidity of Bleaching Earths. A New Method of Estimating Their Decolorising Power", Journal of the Society of Dyers and Colorists, XLVII (1931), p.336.

Vincent, G.P., Dubeau, A.L., and Synan, J.F.; "Bleaching Cotton Goods with Textone Activated with Hypochlorite", American Dyestuff Reporter, XXX (1941), p.358-60.

Vincent, G.P., Dubeau, A.L., Synan, J. F., Carr, R.L., Fenrich, E.G. and Dinges, H.R.; "Elimination of Kier or Jig Scouring by Aldaline Steaming", American Dyestuff Reporter, XXXIII (1944), p.536-38.

Weiss, H. and von Reich, O.R.; "Bleaching Cotton Fabrics and Fibers of Analogous Kind", Journal of the Society of Dyers and Colorists, LV (1939), p.167.

Wheeler, R.S.; "Bleaching and Finishing of Cotton Piece Goods", American Dyestuff Reporter, XX (1931), p.696-97.

Williams, J. G.; "Tensile Strength of Wet and Air-dry Yarns of Cotton and of Viscose Silk After Deterioration By the Action of Ultra-violet Light or of Hypochlorite Bleach", Journal of the Society of Dyers and Colorists, XLVIII (1932), p.167-69.

Bulletins

E. I. Dupont Continuous Peroxide Bleaching Process", Technical Bulletin, 1944.

Pabst Sales Company,; "Notes on Exsize", 1941

Photovolt Corporation; "Photovolt Photoelectric Reflection Meter", 1939.

Rohm and Haas, Co.; "Diastase", 1937.

Will Corporation; "Beckman pH Meter", 1943.